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Psychological Review

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VOL. XXIII. No. 3 May, 1916

THE PSYCHOLOGICAL REVIEW

SOME LOGICAL ASPECTS OF THE BINET SCALE

BY ARTHUR S. OTIS
Stanford University

PART II

THE CRITERIA OF A TEST OF INTELLIGENCE

(Continued from page 152)

If we consider intelligence as a function of age, we will, of course, expect to find the per cents. of children at succeeding ages who pass a given test to increase in a more or less regular way as indicated by the curves in Fig. 11. If the per cents. at succeeding ages do not increase regularly, as in the case of tests XII., 2 and 5 (Kuhlmann, p. 256) of which the per cents. are plotted in Fig. 9, we must conclude either that the data are too meager or else that the test is not a good test of intelligence. In the tests cited the irregularity is doubtless due largely to smallness of numbers tested. Having sufficient data, however, we would have a partial criterion of a test of intelligence. It is but partial for the reason that if the per cents. of children passing a test at successive years do increase regularly we cannot be sure that it is a test of intelligence, since there are other abilities that are also functions of age. Thus, the per cents. of children at successive ages who could span five feet with the two arms would without doubt also increase regularly, since physical growth is also a function of age. There is probably no causal relation, however, between physical growth and intelligence, barring the factor of age. We are therefore in a position to reject certain tests of which the per cents. of children passing do not increase with suc-

ceeding ages; but we must look for further assurance that a test, of which the per cents. passing at succeeding years do increase regularly, is a test of intelligence.

If 500 of 1,000 ten-year children can span five feet with the two arms and 500 of the same 1,000 have intelligences above standard ten-year intelligence, the first 500 will probably not be at all ident cal with the second 500. It may be that 250 of th se who can span five feet are above, and 250 below ten years in intelligence. Similar y, f we knew that 500 out of 1,000 ten-year-olds passed a certain test but that 250 of these had an intelligence less than ten-year intelligence and 250 of those who failed the test had intelligences above the ten-year level, we would be forced to say that in all probability there was no connection between intelligence and the ability to pass the test, or in other words that it was not a test of intelligence. If, however, 450 of the 500 who passed the test had intelligences above the ten-year level, we would be more inclined to think that the ability to pass the test was related to intelligence, to a certain degree at least, and if the 500 who passed the test were the identical 500 whose intelligences were above the ten-year level, we would be sure that the ability to pass the test was very intimately related to intelligence; in other words, that the test was a very good test of intelligence. Thus, if 50 per cent. of ten-year-olds pass a test, the degree of merit of the test as a test of intelligence is measured by the degree in which those who pass it are identical with those whose intelligence is known to be above ten-year intelligence. This degree can be found by correlation.

It will be seen that in order to compare the individuals passing the test with the rank order of the group in intelligence, it will be necessary to have some measure of intelligence, tentative at least. This we may obtain by assuming first by inspection that certain tests which correlate well with age are good tests of intelligence, then building a scale with these, placing each test on the 50 per cent. basis, then testing the coherence of the scale; that is, seeing how well the results of each test correlate as indicated above with the

intelligence order as established by the tentative scale. Then by the process of refinement, that is, by the casting out of incoherent tests (those the results of which do not correlate well with the others taken as a whole), we may eventually more and more nearly approximate a coherent system of tests.[1]

A better method perhaps would be to set up a criterion of intelligence apart from the tests themselves to which the latter may be compared. Thus Simpson,[2] in a study of

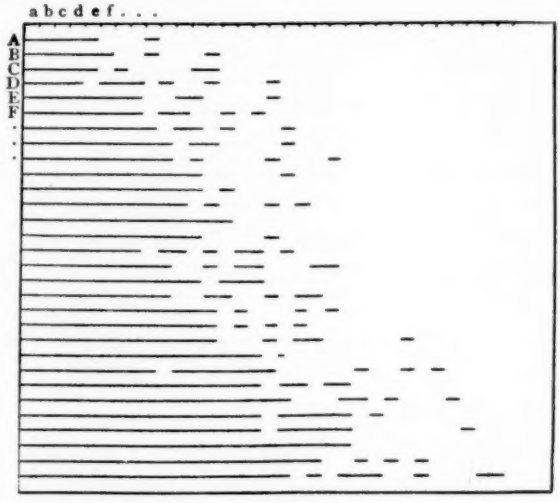

FIG. 15. Showing the distribution of the individuals passing certain tests in a series ranked in order of intelligence on the basis of the whole number of tests passed.

correlations of mental abilities, choses "two extremes of 'general intelligence' as judged by the world." As a 'good group' he chose seventeen professors and advanced students and as a 'poor group,' twenty men 'who had never held any position demanding a high grade of intelligence.' Burt,[3] in a study of the correlation of the specific abilities, had the head master of the school and others rank the boys tested on the basis of general opinion as to their intelligences.

[1] This method has been used by Terman in selecting tests for the Stanford Revision of the Binet Scale.

[2] Benj. R. Simpson, 'Correlation of Mental Abilities,' Col. Univ. Cont. to Educ. no. 53.

[3] Cyril Burt, 'Experimental Tests of General Intelligence' (two figures), *Brit. J. of Psych.*, Dec., '09.

Fig. 15 shows the actual results obtained by Terman in submitting certain tests, *a*, *b*, *c*, *d*, *e*, *f*, etc., to certain individuals *A*, *B*, *C*, *D*, *E*, *F*, etc., of a given age. The presence of a line indicates that the individual passed the test. The individuals have been arranged in the order of their mental ages as computed from these tests and the tests have been arranged in the order of difficulty as determined by the number passing each. While these numbers of tests and individuals are far too small upon which to base a judgment, the figure will serve to illustrate the difference between tests the results of which correlate well with intelligence, as exemplified by test *c*, and those of which the results do not, as exemplified by tests *e* and *f*.

It must be realized that it is entirely possible, theoretically at least, to have a perfectly coherent system of tests which are not tests of intelligence. If, for example, we had begun by choosing tests of physical strength, then by the method of choosing further tests by their degree of coherence, we would be building a coherent system of tests not of intelligence but of physical strength. Therefore it is necessary to use a third criterion in our choice of tests, more particularly at the start when we are choosing those tests with which the later choices are to be compared. In fact, our definition of intelligence is, in a measure, established by the first choices. Suppose, for example, that our first tests chosen were tests of reasoning power; later tests, chosen because of good correlation with the first, might give us quite a different type of tests from what we would get by beginning with memory tests.

It should be noted that whether or not we consider that the degree in which a test is a test of intelligence is measured by the degree of correlation between it and the other tests of the scale, depends upon whether or not we consider intelligence as a 'general factor.'[1] For example, suppose it is suggested to incorporate in the tests a test of the ability to 'carry a tune.' We know that the lack of this ability is

[1] For a discussion of this point see B. Hart and C. Spearman, 'General Ability, Its Existence and Nature,' *Brit. J. of Psych.*, 1912, 5, 51–79, also Burt, *loc. cit.*

largely attributable to lack of endowment of a certain character. If we consider success, adjustment, adaptation, happiness, etc., as aims, and the attainment of these as a measure of intelligence, then we can hardly exclude musical ability from the category of intelligence. But because the ability to 'carry a tune' is not particularly related to the ability to pass the majority of the other tests already chosen to test intelligence, it is considered by some as not a test of intelligence. There would seem to be no reason, however, why the element of endowment in the ability to carry a tune should not be considered as an integral part of intelligence except as we desire, arbitrarily, to define intelligence in another way, for example, as a general factor, or as that character common to the majority of tests. Without going into the discussion of the distinction between the kind of acts requiring intelligence and those which do not, is it not obvious that such a distinction is made, either consciously or unconsciously, when those tests are chosen which are to serve as criteria of those to be chosen because of coherence with them?

To sum up, the three criteria of a test of intelligence are, (1) Do the per cents. of children at succeeding ages who pass the test increase regularly? (2) Do those who pass it also exceed those who do not, in the number of other tests passed? and (3) Are those who pass the tests generally conceded to be more intelligent than those who do not?

The Spacing of Tests on the Scale

As Dr. Terman has pointed out, there is one consideration in the way of placing the tests at equal intervals along a year scale, that is, a scale in which equal units measure successive years, and that has to do with the character of the growth of intelligence. Yearly increments of growth of intelligence are generally believed to decrease with increase of age to about the age 16 or 18. If, for example, the amount of difference between 13- and 15-year intelligence is no greater than that between 12- and 13-year intelligence, then a child would have an opportunity to more than make up for failure of

tests between the ages of 12 and 13 by passing tests between the ages of 13 and 15 on the scale. Therefore, before the scale can be perfectly graduated it will be necessary to know approximately the shape of the curve of growth of intelligence, in order that the tests may be spaced equally as to absolute distances on the scale. If the tests were so placed, the easiest way to score them would be to count the tests passed and from the number found to determine the mental age from a table especially prepared. Thus suppose that from a consideration of the curve of growth of intelligence we deem it advisable to place 9 tests in age-group 3, 9 tests in age-group 4, 8 tests in age-group 5, etc., as shown in Table I., the total number of tests being 88. If these tests were grouped as recommended so that the ten-year group, for example, contains tests which are found by the standardization on the 50 per cent. basis to be standard for ages ranging from 9 to 10 years, then a score of 88 tests correct, or 88 'points,' would mean 18-year intelligence, a score of 87 'points' would mean $17\frac{1}{2}$-year intelligence, a score of 86 'points' would mean a mental age of 17 years, etc., as shown in Table II.

TABLE I

Age-group	Tests
3	9
4	9
5	8
6	8
7	7
8	7
9	6
10	6
11	5
12	5
13	4
14	4
15	3
16	3
17	2
18	2

TABLE II

Tests Passed	Score (Mental Age)
88	18
87	$17\frac{1}{2}$
86	17
85	$16\frac{1}{2}$
84	16
83	$15\frac{2}{3}$
82	$15\frac{1}{3}$
81	15
80	$14\frac{2}{3}$
79	$14\frac{1}{3}$
78	14
77	$13\frac{3}{4}$
.	.
.	.
.	.
9	3

It will be seen that in this way the value of a test is automatically determined by the mental age at which the child happens to be. A test in one group is automatically equated to that test in any other group for which it is considered a substitute or the failing of which it is considered as counter-

balancing. In this regard it may be considered a "point scale." A scale of this kind can be made for the degrees of performance in a single function or ability such as immediate memory for digits, etc., for purposes of correlating degrees of certain functions or abilities with intelligence, computed or estimated, etc.

Prognostication

If we knew the exact relation to one another of the curves of growth of intelligence for individuals of varying degrees of brightness, we would be in a position to prognosticate as to the probable maximum intelligence that would be attained

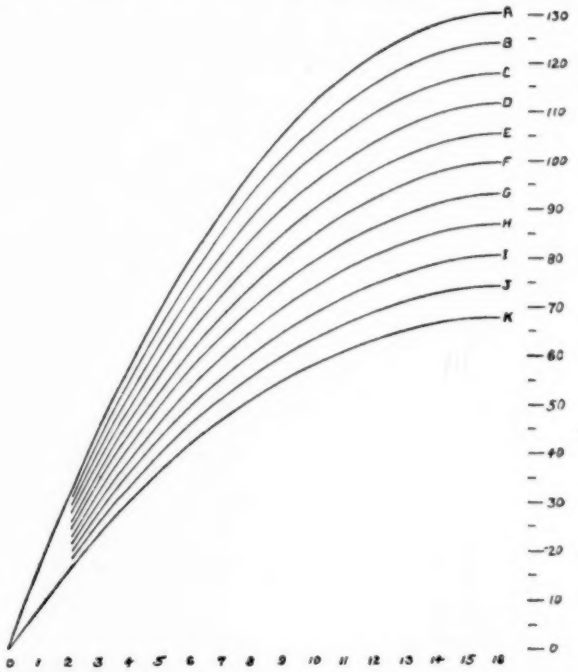

Fig. 16. Hypothetical curves of growth of intelligence of individuals of varying degrees of brightness.

by any individual of whom we knew the intelligence at any age. Hypothetical curves of growth have been drawn in Fig. 16. Curve *F* was drawn first and in accord with the generally accepted theory as to the growth of intelligence.

Then from this curve the other curves were derived on the assumption that all individuals reach maturity at the same age, which in this discussion will be assumed to be 16 years, that they all attain one half of their maximum absolute

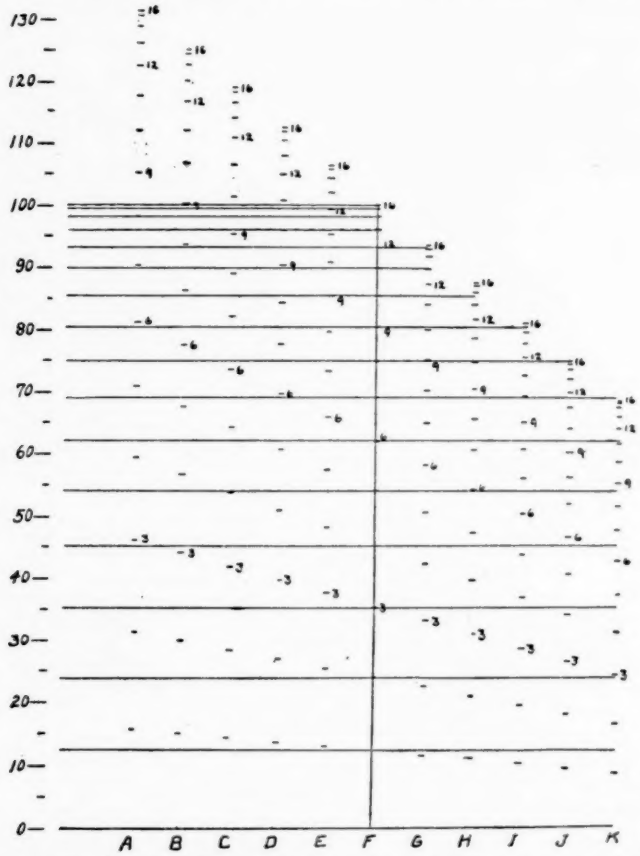

FIG. 17. Showing the relation of the degrees of intelligence at successive ages of individuals of varying degrees of brightness with the degrees of standard intelligence at the various ages and with a graduated absolute scale. This figure was derived from Fig. 14.

intelligence at the same age, and all other corresponding fractional amounts of absolute intelligence at the same age. Guided by this theory, the curves were drawn such that, mathematically speaking, if the equation of the standard curve be considered as $y = f(x)$, in which x measures the

age and y the intelligence, then the equations of all the other curves would be $y = kf(x)$, in which k is a different constant for each curve. Thus since the maximum absolute intelligence attained in curve G was 15/16 of that attained in curve F, the absolute amounts of intelligence or the lengths of the ordinates at all the other years were made just 15/16 of the corresponding ones in curve F, k being in this case 15/16. The other curves were similarly drawn. For the purpose of comparing the absolute amounts of intelligence at the various ages on the various curves Fig. 17 was constructed, in which the horizontal dashes in vertical column A, for example,

TABLE III[1]

Age	Intelligence	Retardation	I. Q.	Intelligence if I. Q. were Constant
6	5	1	.83	5
7	5.8	1.2	.82	5.8
8	6.5	1.5	.81	6.7
9	7.2	1.8	.80	7.5
10	8.0	2.0	.80	8.3
11	8.7	2.3	.79	9.2
12	9.2	2.8	.77	10.0
13	9.7	3.3	.74	10.8
14	10.1	3.9	.72	11.6
15	10.4	4.6	.69	12.5
16	10.5	5.5	.66	13.3

mark the degrees of absolute intelligence attained in successive years on the curve A in Fig. 16. Suppose the mental age of a six-year child were five years and we wish to predict to what maximum intelligence he will probably attain. The method would be as follows, supposing the curves in Fig. 16 to be the true curves. Examining these curves or the columns of dashes in Fig. 17, we would find that the child was progressing along the curve H, on which six-year intelligence just equals

[1] It should be remembered that the figures in this table and Table IV. are taken from a hypothetical curve, the exact shape of which is by no means known. It may be, for example, that intelligence does not reach maturity until the age of twenty, in which case the intelligence quotient would decrease with age at a much slower rate than that indicated in Table III. In fact recent investigation by Terman shows that the intelligence quotient may be considered as practically constant up to the age of fourteen. This fact merely indicates that intelligence really does mature at an age considerably above fourteen. It in no way alters the fact, however, that beyond a certain age, which must be determined empirically, the intelligence quotient cannot be treated as a constant.

standard five-year intelligence. Examining the intelligence of an '*H* child' at 16 years, we find that it is just equal to the standard intelligence of 10½ years, which, therefore, is the probable maximum intelligence that the child will attain. In fact, the probable intelligence at any other age can be found as well. Thus, comparing the positions of the dashes in column *H*, Fig. 17, with the horizontal lines representing the standard intelligence at various ages, we see that the child's intelligence at the various ages would be as shown in columns 1 and 2 of Table III.

The retardation in years is shown in the third column and will be seen to increase with age. This, therefore, cannot be used as an index of the degree of brightness of the child. An attempt has been made to use as an index of the brightness a value called the "*intelligence quotient*" (I. Q.) which is considered to be the quotient of the intelligence at any age divided by the standard intelligence of that age. Up to the age of intellectual maturity this amounts to dividing by the chronological age. The value of this quotient at the various ages is shown in column four in the table. This will be seen to vary also with age although to a less degree than the retardation. In column five are the successive values of the intelligence that we would expect if the intelligence quotient were constant all the way up from the age of six. It will be seen from this column that if we assumed the intelligence quotient constant, we would predict that the child would have an intelligence at the age of 16 equal to standard intelligence for the age of 13.3 years, while by the curves it is found to be equal to standard intelligence for the age of 10½ years. We see therefore that it would not be safe to use the intelligence quotient as an index of the child's brightness, for obviously a child having an intelligence quotient of .83 at the age of six is considerably duller than a child having this intelligence quotient at the age of 16.

When we come to consider the growth of intelligence of a child who is above normal we encounter still more difficulty. Let us suppose a second six-year child is found to have an intelligence slightly above standard seven-year intelligence,

such that he might be considered as progressing on the curve, *D*. (See also *D*, Fig. 17.) In Table IV. are given the mental ages that he would have at the various ages, amount of advance at each age, the I. Q. at each age and the mental age that would be expected if the I. Q. held from the age of six.

TABLE IV

Age	Mental Age	Advance	I. Q.	Mental Age if I. Q. Were Constant
6	7.2	1.2	1.2	7.2
7	8.5	1.5	1.22	8.4
8	9.8	1.8	1.23	9.6
9	11.2	2.2	1.25	10.8
10	13.0	3.0	1.30	12.0
11	16.–	5.0–	1.48	13.2
12	?	?	?	14.4

It will be seen at once that after the age of eleven there is no mental age that we can assign to the child which will be in terms of the intelligence of the standard child. Various terms have been applied to the grades of intelligence above standard 16-year intelligence. They have been called '17-year,' '18-year' intelligences, and 'low adult' and 'high adult' intelligences. Any one of these terms is of course inconsistent with the method now used to designate standard intelligence which for each chronological year is the intelligence of the median individual of that age, for if it be assumed that intelligence reaches a maximum at the age of 16, then '17-year,' '18-year' or 'adult' intelligence is the same as 16-year intelligence except as otherwise arbitrarily defined. While this inconsistency is probably well recognized, a system would, of course, be better in which there was no such inconsistency.

AN ABSOLUTE SCALE OF INTELLIGENCE

If we wish to have a single number as an index of the brightness of any child, we have but to measure the intelligence in absolute units and our index will be the value of k, which is the absolute intelligence quotient. It is the quotient of the absolute intelligence at any age divided by the intelligence which is standard for that age. To find this absolute

intelligence at any age we have but to measure the ordinate of the standard curve at that age. To find the absolute intelligence quotient of a child, for example, who has five-year intelligence at the age of six, we have but to divide the ordinate of the standard curve at five years. For this purpose the absolute scale should be graduated. Let us consider the unit of absolute intelligence to be 1/100 of standard 16-year intelligence. We could then construct a scale, as shown in Figs. 16 and 17, divided into equal units and so graduated that the 100 point measured standard 16-year intelligence. We could then change intelligence of a certain age-grade immediately into intelligence of the corresponding absolute grade. The measure of the absolute grade of intelligence of any child at the age of 16 would be the absolute I. Q. of that child, and vice versa. Now we have a perfectly consistent method of naming intelligences below and above standard 16-year intelligence. Since standard 16-year intelligence is now intelligence of grade 100, above this will merely be grades of 101, 102, etc.

It will be seen that for purposes of prognostication it is not necessary to know the shape of the curves of growth of intelligence. All we need to know is the relation between them. All we need to know is that if the mental age of a six-year child is five years, at the age of seven his mental age will be 5.8 years, at eight, 6.5 years, etc., as given in Table III., column 2. From this table, therefore, we could prognosticate with reference to this child and with other tables with reference to other children without knowing the shape of the curves of growth at all, although of course we could only predict the probable maximum intelligence of a child in terms of the intelligence of the standard child at a certain age and would not know what fractional part this was of maximum standard intelligence.

This brings up the question of the standardization of tests for grades of intelligence above standard 16-year intelligence. This may be done in the following manner. If we assume the curves of distribution of absolute intelligence to be symmetrical this will mean that the grade of intelligence

passed by 25 per cent. of 16-year-olds will be as far above standard 16-year intelligence as that grade is below it which is passed by 75 per cent of 16-year-olds, and the same for the other per cents. Thus if it were found that intelligences graded 90, 80, 70, and 60 were found to be exceeded by respectively 72 per cent., 88 per cent., 95 per cent., and 98 per cent. of 16-year-olds, then we should define those grades of intelligence as 110, 120, 130, and 140 which were passed by respectively 28 per cent., 12 per cent., 5 per cent., and 2 per cent. of 16-year-olds. The per cents. of 15-year-olds, 14-year-olds, etc., which exceeded these amounts could then be combined with these for the purpose of standardizing tests on the basis of several per cents. In the light of the preceding paragraph it will be seen that whether the grades of intelligence called 110, 120, etc., are correctly defined or not will have no particular effect upon prognostication. Whether or not a certain individual has an intelligence just 13/10 of intelligence of 100 (standard 16-year intelligence) is not of so much interest as to know that he has an intelligence exceeded by only 5 per cent. of persons.

The Spacing of Tests on a Scale of Difficulty.—As has been sa'd, we should endeavor to space our tests as evenly as possible on the absolute scale of difficulty in order that a person tested may have the same number of chances to pass a test above the level of his age as he has to fail one below the level of his age. The simplest way to accomplish this is to place an equal number of tests in each space of ten units on the absolute scale, and in order that the scoring might be done with greatest ease this number should of course be ten, preferably, of course, one within each unit. In counting the tests we should then proceed as if the tests extended to the bottom of the scale; that is, a child passing all the tests up to the mark of 50 would be given a score of 50, plus one for every test passed above this point. A person passing tests up to the level of 16-year intelligence would then receive a score of 100. The score of any person who had reached maturity in intelligence would then be a direct measure of his absolute intelligence quotient—the index of his brightness.

The index or absolute I. Q. of a child of a lower age would, of course, be obtained by dividing the score by the absolute measure of the intelligence which was standard for his age. The absolute values, 30, 40, etc., to 100, are seen by comparison of the two scales in Fig. 17 to be equal respectively to intelligences standard for the ages of 2.6, 3.5, 4.5, 5.7, 7.1, 8.9, 11.0 and 16 years. Between each two of these values there should be placed ten tests. The ten tests which should compose the next group should be passed by per cents. of 16-year-olds between 50 per cent. and 28 per cent., the next ten between 28 per cent. and 12 per cent., etc., according to the plan outlined.

Summary

1. Since, for purposes of determining intelligence in age-gradations, standard intelligence for any age has been generally though implicitly defined as median intelligence at that age, from which it follows that the age-gradation of any given amount or degree of intelligence is the age at which it is exceeded by just 50 per cent. of children, and since it is to be assumed that the age-gradation applied to a test is the age-gradation of the amount of intelligence which is required to pass the test, therefore the age-gradation of any test can be none other than the age at which just 50 per cent. pass it.

2. If tests are grouped together in age groups such, for example, that the tests in age group X. are standard for ages ranging from 9½ to 10½, or such that the number of tests standard for ages above ten is probably equal to the number standard for ages below ten (as would be the case by chance if the tests were placed roughly as near ten as possible), or if the tests were all standard for exactly the age of ten, then the proper way to score them would be to give the child tested a score of ten years in mental age if the number of tests passed equalled the number to and including one half of the ten-year tests, and the same for the other years. If, however, the tests are to be scored as at present, giving a score of ten years of mental age only when all the tests to

and including those in group X., or an equivalent number, are passed, then group X. must be composed of tests standard for ages ranging from nine to ten, or all standard for nine and a half.

3. A test may be standardized by reference to the per cents. of children passing it at several different ages or to the per cents. passing it at the same or different ages, obtained by different investigators. In this way greater accuracy may be obtained than by the usual method.

4. To be sure that a test is a test of intelligence, it must be shown, first, that the per cents. of children passing it at the various ages increase with age, second, that the children who pass it are intellectually above those who do not, as determined by a group of tests, and third, that the results of the tests as a whole correlate well with general opinion as to what constitutes intelligence or an established definition of intelligence.

5. If it be assumed that the yearly increments of the growth of intelligence decrease with age, then in order that a child may have no more opportunity to pass tests above the level of his age than he fails below it, it is necessary to put fewer tests in the upper age-groups. This grouping will have to be made at present on the basis of a hypothetical curve of growth, equal numbers of tests being placed in equal portions of an absolute scale derived from the hypothetical curve of growth. At such time as a curve of growth can be obtained from actual data the grouping can, of course, be corrected.

6. If we assume that all individuals attain intellectual maturity at approximately the same age, and that of the final absolute intelligence the relative portion attained by any child at any age is the same as that attained by any other child at the same age, then an I. Q. which is the quotient of the intelligence of the child at any age divided by the standard intelligence of that age (both in absolute units), will be constant for that child throughout the growth of intelligence, and will serve as a fixed measure of the degree of brightness of the child.

CONCERNING THE IMAGE[1]

BY HERBERT SIDNEY LANGFELD

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A few years ago Professor Winch introduced the subject of imagery with a fable about foxes, some of whom had tails and some of whom had not.[2] It was soon evident that those who had been deprived of their brush were meant to symbolize the happy possessors of an imageless mechanism. Considering the manner in which the image has been hunted down recently the simile is more apt perhaps than he realized at the time. Notwithstanding the attack which has been made upon the image I am going to assume that it still exists and shall devote my attention to describing what I believe to be some of its characteristic functioning, hoping that such a course will do more eventually to convince its enemies of its existence than theoretical discussion or introspective accounts of its texture.

In using the term image I do not wish to denote a content of consciousness qualitively different from sensation. Recent experimental work seems sufficiently convincing upon that point. I am referring under that name to sensations centrally aroused.

The meaning of an object is our attitude toward that object, our reaction to it. In like manner the meaning of an image is that inevitable change in our organism which follows its appearance in consciousness. This change may consist of immediate motor discharge and accompanying kinæsthetic sensations or in visceral, glandular or similar reactions characteristic of emotional states. In terms of the self we may say that we assume a definite attitude toward the image

[1] This paper was read at the meeting of the American Psychological Association, on December 28, 1915.

[2] 'The Function of Images,' *J. of Phil.*, 1908, 5, 337–352.

just as we do toward the object. The image acts for or represents the object and in doing so acts as a cue for a definite reaction belonging to the object. Of all possible purposes of an image certainly that of representing a situation not present to the senses is the most obvious.[1]

This function of representation is not, however, characteristic alone of imagery, but belongs also to sensations aroused by an external stimulus, and cannot therefore be used to distinguish it from the latter. The following illustration makes this point evident. If one comes suddenly upon a white sheet hanging upon a line in the moonlight one will probably inhibit one's mechanism for advancing and at least prepare for retreat. This will be readily recognized as a ghost reaction. The situation means ghost. It may be that our sensations will be supplemented by imagery and that we shall actually perceive a ghost. I am inclined to believe that in many instances if not always the imagery which completes the perception accompanies or follows the reaction rather than precedes it and that the externally produced sensation is the sole cue. When we think ghost it may happen that we shall have not a complete image of a ghost but a fragmentary one of the white sheet. Here the image alone is the cue and as in the case of the perception the reaction, to a large extent emotional, is the ghost meaning.

I have purposely chosen as an illustration an incomplete representation, *i. e.*, the white sheet for the whole ghost. The image may be an almost perfect likeness of an object. In most cases, however, it is not; and often it is so far removed from the original object that to say that it means the object

[1] Colvin says in 'The Learning Process,' p. 111: ". . . the meaning of a situation is after all an attitude, and that attitude must in the last analysis be a motor affair. Thus it is but a step to the conclusion that this general dependence of experience for its significance on motor adjustments had left a deposit or 'mind-stuff' that symbolically represents concrete situations, not actually present, but ideally represented."

Hollingworth writes: "Their place (objects of perception) is taken by any content, revived, perseverative, or immediately sensory in character, which happens to be easily available at the time. These processes, by a sort of substitutional rôle, come to represent and impersonate the object between which the relations, as socially recognized, would be said to hold" ('Vicarious Functioning of Irrelevant Imagery,' *J. of Phil.*, 1911, **8**, 691).

seems on the face of it almost absurd.[1] But from what we know of the laws of association one thing is certain, namely that a hundred different images can introduce almost the same reaction, and if the reaction is the meaning then a hundred different images can in this sense stand for the same meaning, although ninety-nine of them must of necessity be what I should like to call inadequate images, if I may borrow an adjective used in the case of stimuli arousing paradoxical sensations.

Several years ago I obtained introspective accounts of imagery occurring in experiments on inhibition and hitherto unpublished.[2] As the introspection seems to me especially interesting among other things for the clear evidence of the motor attitude which attaches itself to what without due consideration of this setting would appear totally irrelevant imagery, I should like to introduce it here.

A method of experimentation was desired by which the subject would be required to suppress some very strong association. With that in mind the alphabet and the numerical series were selected. There were five subjects, all students of the Harvard Psychological Laboratory. Each was asked to repeat the alphabet as rapidly as possible and the time was taken with a stopwatch. Then he was asked to repeat the alphabet again omitting the letters f, l, r and x. The signal to begin was given about two seconds after the instructions and the time to repeat the alphabet again taken. This test was given in connection with other experiments, so that only one test was made each week, the series extending through about two months. The next week the subject was

[1] I am thinking particularly of the classic example of the image for 'but' described by Professor Titchener. The presence of inadequate imagery has been repeatedly mentioned in the literature. In the *Philosophical Review*, 1897, p. 650, J. R. Angell writes: "They (images) often shift, and are by no means the same at different times. Indeed, there is no necessity that they should be, representing as they do simply a medium for the performance of a certain function, *i. e.*, the function of meaning a definite thing. Thus the image which serves me in using the concept 'justice' is sometimes a visual image of a state of justice and sometimes simply the auditory word image." ('Thought and Imagery.')

[2] A brief account is given in the report of the meeting of Experimental Psychologists at Clark University, PSYCHOL. BULL., 1912, 9, 236.

asked to omit g, m, s, and y. Similar arrangements were tried for several weeks. Then he was asked to repeat the numbers up to thirty omitting 5, 10, 15, 20, and 25. Then omitting 4, 9, 16, 19 and 26 and so on. Toward the end he was asked to omit the even numbers and finally to repeat the numbers in reverse order omitting 27, 18, 12, 9 and 4. Introspection upon the fore period (V.P.) and the main period (M.P.) was asked for at the end of each test.

From the full introspection I have selected the portion essential to an understanding of the imagery and manner of inhibition of each subject. Arranged according to the subject it is as follows:

Subject *A*

1. V.P. Auditory kinæsthetic, 'Omit f, l, r, x.' M.P. When I came to the letter to be omitted I made a short pause. Visual image of 'f.' Felt an inhibition.

2. V.P. There was a visual image of the letters and auditory image that I must not say them.

3. (As the experiment progressed we find) the fact that I was to omit the letters was not strongly represented in consciousness, but the letters themselves were much more prominent (in the V.P.).

4. V.P. Before I started I went through (skipped) from 5 to 7. 6 came up visually. (He was to omit 6, 11, 17, etc.) There was no tendency to say it.

5. (Finally we have): M.P. When I came to the one to be omitted, it came up as visual and auditory image, but no kinæsthesis. The inhibition was so conscious (powerful) that there was no attempt to say the number to be omitted.

Subject *B*

1. V.P. There was the visual imagery of the number scheme. I thought that when I came to them I must be careful. M.P. When I came to 4 I knew that I must stop.

2. V.P. I suppressed the numbers as I went along. I saw where the letters were. M.P. When I came to the letter before the one to be omitted I got excited. The letter came kinæsthetically. I felt as if I drew back.

3. V.P. There was the feeling of location of the numbers in a scheme. I felt keyed up when I thought of them. There was mild fear when I saw them.

4. V.P. Visual image of the numbers. I thought of the numbers before the one to be omitted as the ones to stop at. Feeling in throat and tongue. M.P. When I came to the one before the letter to be omitted I recognized the feeling and stopped.

5. V.P. I made myself see the number preceding each one. I tightened up my mouth and shoulders. Rigid feeling.

Subject *C*

1. V.P. I tried to think where the break was. I saw the letters as a series of steps with the letters to be omitted cut out. M.P. As I got to the letter there was a visual image which I had to throw off.

2. V.P. I thought of the letters as holes or notches that had to be jumped over. M.P. They came up kinæsthetically. As they came up I saw the breaks. This shut off the letters.

3. V.P. The letters were represented by hurdles to be leaped over.

4. M.P. Hurdles repeated. I did not see the numbers at all. They came up kinæsthetically and I had to inhibit them. All the time I was conscious of the field of hurdles.

5. V.P. The series was represented by a broken chain. M.P. I saw the break when I started. The number came kinæsthetically. I forced it back according to the visual image. That is what seemed to help me inhibit the number. Later the inhibition took care of itself.

Subject *D*

1. V.P. Visual image of immense gaps to be leaped. M.P. When I reached the letters to be omitted there was an auditory image of the letter and a clenching and stopping. A feeling went down as far as the diaphragm.

2. V.P. Visual image of the five letters to be omitted on a card. I knew I should have to stop at f. (g was to be omitted.) Nothing for the other letters. I trusted to luck for them.

3. V.P. Visual image of a stony field. The stones were numbered with the letters to be omitted. They were as obstacles. M.P. The numbers did not come into consciousness. I just stopped for some reason at the number before, and groped about.

4. V.P. Visual image of a football game. The numbers were represented by men whom I was to pass. M.P. I ran with the ball. The man who reminded me of six threw himself forward. I did not say six.

5. V.P. A visual image of a piano key-board. My idea to omit the numbers was to leave out the black keys while playing.

SUBJECT *E*

1. V.P. I went over 5, 10, 15, 20, 25 to myself. I noted that they were at certain stages. I went from 4 to 6. Instruction in mind. M.P. I grouped them in fives, getting the first group from the V.P. As I went on it became easier and easier.

2. V.P. I repeated the numbers five or six times. I do not know how the instruction was present, but I knew that they were not to be said. After memorizing them I was conscious of the instruction to omit them. When I came to 3 (4 was to be omitted) I stopped as if I could not tell what to do. The instruction came into consciousness and I went to 5.

3. V.P. I repeated the numbers to myself and put my fingers down as I said them. I did not think what had to be done to them.

4. V.P. I thought of the numbers preceding the ones to be omitted. When I thought of 19 (18 was to be omitted into the backward series) the instruction was in mind. M.P. When I came to 28 the number to be omitted (27) was in mind, until I started to say 28. It then dropped out and I went over to 26, without 27 coming up again. At about 21 number 18 (the one to be omitted) came up and remained until I began to say 19.[1]

[1] For the most part the introspection, at times inexact in expression, is in the form in which it was given to the examiner. Some of the abbreviated sentences have been completed by me. The subject was not pressed for a more detailed description when he said he 'thought' or such and such was in mind. The experimenter was not at the time interested in the question of imageless thought.

It will be seen that visual imagery was used by four of the subjects and probably by the fifth. In general the method of inhibition was to associate in the V.P. some form of inhibition with the numbers either visually or verbally represented. Sometimes there was a direct association of the inhibition of the vocal organs with the numbers. Sometimes there was an association of the words of the instruction as intermediary. In one instance the fingers were pressed down as the numbers were spoken in the V.P. In another an emotion of fear was associated with the letters. The imagery at times was fantastic, such as notches or hurdles to be passed over or football players to be evaded, but inadequate as they may be they were in all instances of such a nature as to be readily associated with inhibitory processes. They mean 'inhibition' in that they function as such. It will be readily admitted that the perception of the same word can give rise to different meanings according to the setting. In like manner a visual image such as that of a hurdle, which was most strongly associated in the subject's mind with evasion, can in the above situation cause an evasion of a word, that is the inhibition of the vocal organs rather than the more direct association of the lifting of the feet.

In the main period the visual or auditory imagery frequently appeared as a cue and the inhibitory process followed. At times there was probably a direct effect of inhibition from one muscle group to the other. We know that such radiation of motor impulses occurs. The clenching of the fists and the pressing down of the fingers when other muscles are to be inhibited are examples. I feel rather convinced that in the case of inadequate imagery also there is such an action from one muscle center to another, the imagery directly initiating the motor response most readily aroused.[1]

[1] In this connection Wilfrid Lay's remarks ('Mental Imagery,' *Psychol. Monog.*, 1897–99, 2 (3), p. 29) are of interest: "If we attempt to visualize such lines as

'To take up arms against a sea of troubles
And by opposing, end them,'

the result is often the purest visual nonsense." It would seem from what I have said above that the imagery would probably not be nonsense, but a definite motor setting, a brace against an onslaught such as is necessary against the breakers.

The full introspection shows that there is a dropping off of imagery as the tests progressed and even in a single trial the imagery appears only for the first letter or number. The determining tendency—whatever that may eventually turn out to be—grows stronger and reaction follows reaction without the intervention of imagery.[1]

When there was difficulty the image tended to appear again. A good example is that from Subject *B*'s introspection, at the end of the series. He decided not to think of the numbers in the V.P. All went well for three numbers. He failed, however, to omit the fourth and the visual image of the fifth promptly appeared. This reappearance of imagery to help in time of trouble has frequently been observed in investigations on the learning process.[2]

It is undoubtedly because the task set in the above experiments was a difficult one that so much imagery appears so clearly described in the introspection and for that reason the test recommends itself for class-room practice.

The reactions in the above experiments are comparatively simple ones. There is merely an inhibition of the muscles of speech involved. It may be stretching the term to speak of an inhibition as a reaction, but there will be no confusion if

[1] See J. R. Angell, 'Methods for the Determination of Mental Imagery,' *Psychol. Monog.* **13**, (1), p. 70 for a good description of the decrease in visual imagery with practice.

[2] D. F. MacLennan writes ('The Image and the Idea,' PSYCHOL. REV., 1902, p. 74): "Another proof of the close dependence of meaning upon imagery is found in the constant resort to imagery when thought is baffled. . . . The moment, however, that some new thought or some new combination of thoughts arises, we search for the concrete imagery in which the conception may be appropriately embodied."

M. R. Fernald ('The Diagnosis of Mental Imagery,' *Psychol. Monog.* **14** (1), p. 137) writes: "That we have had imagery reported for each of the tasks by each of the subjects may be seen by reference to our experimental data. The certainty and invariability of this response increase with the novelty or difficulty of the problem."

Similarly Book says in a footnote ('The Psychology of Skill,' p. 42): "It is psychologically important that all the images which appeared in the different stages of the writing were first prominent and distinct, then hazy and indistinct, disappearing entirely soon after they had served their purpose in the learning."

See also G. H. Betts, 'The Distribution and Functions of Mental Imagery,' *Teachers College, Columbia University Contributions to Education*, 1909, p. 94. He finds that imagery appears when thought is baffled but thinks that it is "for the most part irrelevant, and hence of no possible service in reaching the solution."

we speak of it as a motor setting. In the more intricate meanings we must look for a more highly organized response and this we find in the integrated action about which recent physiology has told us much.[1] And further there is no reason why a fragment of a most simple image may not be the cue for a very complex and intricate response.[2] A mere ghost of an image may serve as a cue for an extremely involved ghost response. This is particularly true of concepts, for a detailed image would have the tendency to inaugurate a dated and placed response, which is contrary to the purpose of concepts. This has seemed to me the explanation of the fact sometimes noticed that imagery of concepts is likely to differ somewhat from reality. I remember in experiments I made a few years ago they were invariably larger than reality; but that is only one of many possible forms of variation.[3]

A type of reaction to imagery which should be more generally emphasized in the literature is the emotional reaction. We found in the above introspection that the emotion of fear was directly attached to the image. This, of course, frequently occurs and leads most readily to a motor response. There is, however, a large field where the motor response as a practical attitude is absent by reason of the very nature of the attitude. I refer to the field of esthetics. Here imagery is very prominent, especially visual imagery, and the response is generally a subtle emotion with its accompanying bodily changes and empathic motor setting. The prominence of imagery in esthetic enjoyment where there is this non-practical attitude suggests a rather obvious explanation why in general comparatively little imagery is noticed and also why, when introspection discloses an army of clear and vivid visual impressions, many of us doubt the reliability of the introspection. The greater part of our attitudes toward our in-

[1] See E. B. Holt, 'Response and Cognition,' *J. of Phil.*, 1915, 12, 399–400.

[2] J. R. Angell (*loc. cit.*, p. 651): "In so far as an image is simply a symbol of certain experiences, great dimness in it is still compatible with its correct use within limits."

[3] In regard to the function of the image as cue and the importance of the motor setting in general ideas see Münsterberg's 'Psychology General and Applied,' p. 173.

E. B. Titchener, however, states: "I doubt whether particularity or abstractness of meaning has anything essentially to do with the degree of definiteness of my images." 'Experimental Psychology of the Thought Processes,' p. 16.

vironment are practical attitudes. Our interests are directed toward what we can do with an object and how we respond to it.[1] The objects themselves, from the fact that they are mere cues, remain for the most part in the margin of attention while the reactions occupy the fovea. It is the dreamer, the non-practical man, the man out of touch with his surroundings, for whom visions occupy the center of attention. This difference in attention is greater even when not in the presence of the object, that is when imagery is functioning in its stead. Then the slight imagery present in the extreme margin of consciousness of the trained mind is often as little noticed as the *mouches volantes* before the eyes.[2] To ask a subject to introspect upon his thought process must almost inevitably distort to some degree the picture, by bringing the imagery into too much prominence. Yet an argument against its too great prominence is not one against its existence.

I have spoken of the consciousness of the mature mind. From what we have said of the use of imagery in learning, in acquiring specific adjustments, it would follow that imagery is more prominent in childhood and this is what is generally found. I venture the suggestion that there is also much imagery in old age, but for quite another reason. In the late period of life action is of little importance and contemplation fills the soul. Witness the delight in minute and often tiresome description of trivial details.

In conclusion I would say that I thoroughly agree with the Behaviorists that our efforts should be directed with all possible energy toward the refinement of the methods for the investigation of expression. The science owes them the deepest gratitude for their reaction against objectively uncontrolled experimentation. As a psychologist, however, I cannot be satisfied with half the picture nor can I persuade myself that images which I have experienced do not exist, although they, together with sensations, may eventually be further analysed.

[1] See Judd's 'Psychology,' p. 238.

[2] In the classic words of Galton ('Human Faculty,' p. 112), "That it must afford immense help in some professions stands to reason, but in ordinary social life the possession of a high visualizing power, as of a high verbal memory, may pass quite unobserved."

MOVEMENT, CENESTHESIA, AND THE MIND[1]

BY GEORGE VAN NESS DEARBORN

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Although especially favored by the warning of examples given it more directly than usual by the history of philosophy, it can scarcely be gainsaid that psychology, the most properly basal of all the sciences, has suffered not a little stagnation from an excess of deduction in method; there is induction certainly in quantities to be proud of, but, it seems, from a relatively unproductive source. Psychology in its descriptive phases, and in the abnormal aspects as well as the normal, has most often not been wisely based, not founded "flat on the nether springs" of universal bodily movement and function.

Although philosophically born, so to say, in a psychological laboratory, I believe most thoroughly today that the actual laboratory experimentation, indispensable as it is, is not the directest road to a working and real knowledge of mind as a whole. Much of the practical work, to be sure, has been highly productive, the qualitative research especially. It seems, however, obvious today that the same extent of time devoted to a study of the sensation-basis of mind as inclusive of consciousness but much more extensive (in a figurative sense); dedicated to direct empirical knowledge closely correlated with the neuro-musculo-glandular machinery, particulary the coördinating nervous system, would have taken us further. It would perhaps have already placed psychology preëminent in human wisdom, *the acknowledged science of how to live.* Quantitative measurement (unfortunately inherited, just as the laboratories were opening, from the beginnings of the new physiology), psychophysics, "turned its head" in the laboratories,—toward itself; and naturally the science rejoiced in its escape from phrenology,

[1] Read before the American Psychological Association at Chicago University, 28 December, 1915.

already seen to be lost on the wrong road. Even introspection, direct or indirect, the most natural and fundamental of all psychologic methods, has not always worked in the right "places" in the mind, even if it has perchance labored in the right way. But this is changing.

Introspection on a new basis and by a new method is coming in. Only now, instead of "looking within" and noting what is actually "seen," one "looks within" the total personality and judges as to what he ought to see in the light of advancing analysis of the body and of its meanings in this total personality. We might term this potential or even casuistric introspection:—what might be or ought to be found in this manner—under certain conditions. And such a procedure is without taint of "deduction" and is a perfectly proper and valid psychologic method. Any doubt that some may for a moment have about this, must be ascribed to the relative dimness and indistinctness of the subconscious and what therein is; and yet you all, everyone, would readily admit that a misplaced chair against which you fall in your study is no whit less real because at the moment the study chances to be dark. It is so in the subconscious phase of mind.

Some psychologists still lack adequate knowledge of the body, of the material which composes it, and of the universal *motion* to which, even by the often materialistic physicist, this "material" is ultimately reduced. This latter concept motion is indeed the key to the situation, and the obvious psychologic failure to explain mind (for dualism no less than for monism) seems largely dependent on the presumptious and dogmatic refusal of many to admit this category, spatial dislocation, motion, into their explanations and almost into their psychology at all. These even seem to ignore the fact that now, all the while and everywhere, the conceptual bounds between mind and energy, before assumed impassable, are felt to disappear like fog as we advance into the clear daylight of understanding.

The central truth that seems to me indispensable to present psychologic breadth is that the *organism is in universal move-*

ment, movement continuous in both time and space. This is the category "Life." No part of the action-system while alive ever for a moment is at rest, although often, of course, relatively at rest. This universal movement of the body, entirely "immanent," inherent in the deepest nature of organism, must mean something in the personality; and it must be represented in the concomitant mental aspect of the individual; for human personality, above all other finite integrations or Kantian "unities," is the most complete.

Any physiologist whatever who for a moment tried to make this universality of movement explicit to himself or to another would do so quickly and positively. He would think as the most striking circumstance, perhaps, of the *universal tonus* wholly characteristic of living muscle which is half of the body's mass and nearly everywhere throughout its volume. He would find several degrees of tonus ranging from catalepsy through cramp, exertion, waking activity, lassitude, sleep, coma, and paralysis to death itself, where at last its zero is reached. Muscular tonus is continual during life and well-nigh spatially general, and stands in psychology inevitably for the movement or stress or strain which is the concomitant of afferent neurility.

The *necessity of maintaining equilibrium* as a sensational bench-mark or base of measurement and calculation is another universal need in the organism which in a manner quite similar demands the continuous activity of a body animated everywhere and at all times with a motor fabric. The reader may readily assure himself of this with a little careful consideration of ten actual minutes of his own behavior when about his ordinary activities.

Mechanical purchase for many efforts has to be secured; this one may typify by pushing against the wall and noting the general hardness of the muscles as he does so. This maintenance of a resistance-basis is similar in kind with the preservation of equilibrium; these two plainly are special functions of the universal tonus of the organism.

Sherrington has demonstrated the fundamental principle of neuromuscular action termed the *reciprocal innervation of*

functional antagonists. The principle is self-explanatory and means just what it implies: when the fore-arm supinators, for example, are actuated the pronators are actively inhibited, when the flexors are actuated the extensors are inhibited, and so all over the body. So far as protoplasmic changes in the mechanic stresses and strains are concerned, actuators of the sensation-fabric, this duplex process means a more than doubling of the bodily movement.

In conditions of feeling and of dynamogeny, and proportionally thereto, there is apt to be *irradiation of neurility* in the spinal grey and perhaps in the cortex, "across country" so to say, and not by the more usual channels of communication. One sees this in convulsions, in "hysterics" (and very possibly in delirium tremens). It means a large increase in the motivity of the body.

In addition to this elaborate mechanical vivacity throughout the body's volume, there are the two unending series of specially innervated movements in two classes, vegetative and personal or voluntary, as I have emphasized so much for the comprehension of sundry conditions. The vegetative motions are automatic, reflex, autonomic, instinctive, emotional, or habitual, but each extensive spatially more or less in the body, and each a movement registered by receptors. The voluntary movements I have discussed elsewhere,[1] and they are characteristically universal in the organism both muscularly and neurally. Moreover, there is absolutely no assignable limit to the extension of voluntary control in the vegetative organism.

Finally, mechanical respiration, circulation, digestion, and excretion each are all-pervasive muscular hydraulic processes whose direct influence is continually felt in a material way throughout the organism.

Now pardon me for expressing the firm belief that the only reason the average academic psychologist ordinarily ignores all this mass of intelligent and beautifully adapted movement throughout every human body from birth to

[1] Notes on the Neurology of Voluntary Movement, *Medical Record*, New York, 18 May, 1912.

death, is that he does not *realize* it, does not, practically, in frank truth, know it nor appreciate its meaning in the mental control of behavior; in short its primary necessity to a successful psychology. Some do not realize how most intimately interwoven are automatic movements with the voluntary, or how very readily subsensory impulses become plainly sensory. Plasticity, mental as well as protoplasmic, requires present emphasis.

For years in my psychological classes, for example, we have discussed at some length a topic which would surely meet with the full approval of the great John Locke, wise prophet of several important things whose fullness is yet to come, three centuries after the brain that "synthesized" them was already mould. This topic we termed *Cenesthesia*, explained as good modern American from the ancient "koinos," common, and "aisthesis," sensation. Cenesthesia was said to consist of two complementary groups of sense-experiences: one kinesthesia, particular sensation of movement; and the other the cenesthesia proper,—both together making up the sensation-fabric, the empiric skeleton of mind conventionalized as the subject of a natural experimental science. The kinesthesia is described as including "touch" and with nine or ten functions. These kinesthetic uses are (1) the representation to the integrating nervous system of bodily and environmental movement, each of both the active and the passive kinds. (2) Posture in a broad and general sense. (3) Stereognosis, the recognition of shape internal, within the hands or arms or legs, and external, in a room or along a devious pathway. (4) Appreciation of weight, weight of the external bodily parts as well as of external objects. (5) Maintenance of equilibrium, whatever the posture or the mode of personal locomotion. (6) Sensing of jolts, jars, and material vibrations coming from the environment. (7) Pressure and impacts other than jolts and vibrations. (8) Elaboration (and recording?) of the motor ideas through which the body is moved and controlled. (9) The spatial relationship of local sensations: local sign. (10) "Rhythmic control of the circulatory compression of the veins."

It never needs elaborate demonstration to convince students that the movement-sense so connoted involves continually practically every portion of the organism and with a variety of sensations or of afferent influences roughly indicated perhaps by the dozen or more histologic forms of receptors. Be the "variety" or the uniformity as it may be, here at all events is ample psychophysiologic country for survey, careful study, and cartography.

Cenesthesia proper, the sensation-fabric, ground at once of the subconscious and the fully conscious aspects of mind, is merely indicated in our class discussions and not at all described. It will bear, none the less, an indefinite but large amount of description. Some men are already beginning to practically realize this—clinical neurologists, psychopathologists, physiologists, and a few academic psychologists who have not remained under the cataleptic influence of the "five-senses" bugaboo. This is one of those traditional simple concepts that seize the common knowledge like an opiate and hold it shut for years or decades or centuries to the passing and evolution(!) of time. Vision and hearing and taste and smell are part, but only part.

Experience has shown that probably the easiest and certainly the surest way of reminding a student-class of their respective cenesthesias, is to suggest the somatic regions and systems where its mental aspect is most obvious. This category and *feeling-of-being-alive* comes in a flood from the body alive, as may be felt from the following suggestions. Until one has been dead, so that the contrast between living-cenesthesia and dead blankness and lack and mere materiality can be actually appreciated, personally and vividly, no one has sufficient sanction to categorically deny this flood of neurokinetic influences, dynamic index of the mind in its relationship to matter.

Richer than any other one region, probably, in cenesthesia is the *head*, partly because vision, hearing, taste, and smell are spatially placed here, but partly owing also to the surpassing complexity of structure and of function herein located: There is an elaborate vascular mechanism within and around

the brain, a hydraulic system with plenty of sensation related to it. There are muscular and articular strains of unequalled complexity, since the face is the great expression-organ of the personality; one thinks of the scalp, the eyes, the mouth particularly. The interior of the head below is rich with sensations other than those of taste and smell and movement proper; think of the extensive and complicated nasal fossæ, the eustachian tubes, the middle ear; the dental alevoli and the teeth themselves. Brain-action gives undoubted sensation whether its disputed nature be one or another; and "nerve-tire," cerebral fatigue, has a complex and strong sensation like no other. Atmospheric electricity occasions head-experience which needs elucidation further. These are some of the "sensations" coming from the head and neck.

As for abnormal cenesthesia (pain) in the head, A. Neuman devotes more than thirty pages to it in Behan's momentous treatise, "Pain," 1914, and many varieties and causes are described.

To the present writer it seems absurd and nothing less to ignore in one's philosophy a flood of afferent influences, sensory and subsensory, coming from regions as extremely complex as these. A better knowledge of anatomy and of physiology would make some college psychologists admit it, some for whom still cenesthesia and subconsciousness are largely sources of innocent merriment, so strong are the traditional chains.

The mechanical *respiratory apparatus* directly and indirectly involves the entire body, and the chemic respiratory interchange in another sense may possibly make dim but extensive contributions to the "common sensation." The properly kinesthetic factor of this is obvious, for it concerns the entire thorax and abdomen inside and out, and muscularly the legs and even the arms and neck. As is sometimes said, it probably makes larger donation to the pleasantness of being alive than does any other process whatever. In the nostrils, nasal fossæ, larynx, trachea, bronchi, possibly in the alveoli (over the afferent vagus) arise a host of influences for the nerve-centers, the complexity of which would be appre-

ciated only on detailed consideration of the very numerous different tissues and structures and processes involved. The abnormal cenesthesia of the respiratory relations is correspondingly various.

The *hemolymph circulatory mechanism*, "the circulation," has a larger confluence of afferent messages concerned with it than most psychologists realize. The normal conditions are chiefly related to emotion, of course, and in particular is the heart involved, especially in fear and in joy. The writer has been interested in the vaso-motor aspects of this particular phase of cenesthesia and is convinced that these material changes in the diameter and in the compressibility (due to blood-pressure changes) of the arteries (and perhaps of the veins?) play no small part in the common sensation, especially that which is on the frontier between a sense of fullness and one of unpleasantness (or pleasantness) from congestion verging on inflammation. Muscular and general atony, too, may have part of its felt languor, etc., from local or universal pressure-lacks within the tissues. In certain parts of the body, especially in the reproductive mechanism, these vascular pressure-differences are mentally conspicuous, so that their cenesthetic capability is certain. In the "rubor, tumor, 'thermor,' and dolor" (an ancient lesson in inflammation), the importance of the abnormal degrees of these reactions is obvious.

The contributions to cenesthesia arising in the heart itself seem to be chiefly of two sorts, those due to unusual heart-rate and to over-action, and those of an abnormal nature. Much of the sensation related to the cardium and its tensions is pain, endocarditis, acute dilatation, mitral incompetency, ganglionic degeneration, angina pectoris being among its commoner occasions. It is important to note however that Behan states explicitly that the "raising of the intraventricular tension often causes cardiac pains"; if pains "after pronounced exertion," why not pressure sensations from lesser degrees of tension, and (in theory) always?

The vagal 'depressor' influence, representing general vasomotor adaptation, seems to have no little weight in the

emotions, and to be a rather important factor in the mental aspect of moods and perhaps of temperaments. All such matters, at present dumb, need to be given scientific voice. For example, the surprisingly general "depression" of both mind and body late in the afternoon, euphoria depressed into dysphoria, by simply the absence of an accustomed cup of coffee at lunch. Much of such an effect has its affective basis apparently in some thing like a contrast-effect related to heart-action.

The *nutrition mechanism* is the seat of more cenesthetic consciousness and subconsciousness probably than any other system, partly because of its great size and considerable complexity and partly because morphologically it is largely a body surface, exposed therefore to part of the environment directly. This integrated set of vital implements has been studied, too, by people with psychologic interests more than has any other viscus, by the physiologists Beaumont, Cannon, Carlson, Crile, and observers abroad, and by a few psychologists, of whom the latest to report is E. G. Boring in the PSYCHOLOGICAL REVIEW, July, 1915.

As has occurred occasionally in other respects, Boring's interpretation seems a bit less scientific than his research-results proper, as if possibly somewhat restrained by tradition and too little oriented in the light of certain pathological data. It is ungracious surely to suggest this, especially when just this kind of study of every portion of the organism is precisely what is most needed to revivify and stimulate our science to accurate description of things as they are and then to their satisfactory explanation.

The digestive and absorptive apparatus has a great richness of structure, of process, of nerve-supply of every kind, and of indirect mechanical relationship to the remainder of the torso at least.

This last can not be ignored in a discussion of this kind, since the psychologist is concerned with mental processes related to living practical processes as they actually are and not often with mere anatomic units which exist as units only to be inseparable parts of a living whole. Many a student

of physiology, of physical education, and of psychology, and many an instructor of anatomy, forgets this or never learns it, and is thereby misled into a wrong because partial view. 'Referred pain' is a case in point: the psychologist, like the clinician, is concerned chiefly with the practical place of origin, in a functional sense, of the pain, and not much with the spatial location of the local experience based on neural distribution.

The mouth is rich in sensory and 'emotional' data from the lips to the pharynx—months of questionary work would not exhaust this one little end of the alimentary canal termed by some unpoetic German the funnel of the stomach. The pharynx is relatively passive, yet with both vegetal and voluntary muscle in its walls. The esophagus, especially its lower, cardial end, has possibilities of rich sensation, chiefly painful but by no means wholly so. Consider then the twofold stomach, the pyloric valve, the small intestine, the pancreas, liver, gall-bladder, bile-ducts, the ileocecal valve, the appendix, the colon intimately connected with the stomach and with the supporting diaphragm and pericardium upward even to the shoulder-girdle. The sigmoid flexure and the rectum with its important sets of sphincters, reflex and voluntary, certainly have an important place in the consciousness as in the subconsciousness of the individual. The complicated movements of the intestine and the borborygmic events provide a considerable tributary to the stream of consciousness even under normal circumstances of mind and of bowel. When the mind is hypochondriacal, hysterical, or paranoic, and when the bowel is inflamed so that the movements and the secretions are vastly increased, or atonic so that there is constipation, there is positively no assignable end to the sensations to which the nutrition-mechanism proper may give rise in consciousness. Motor, secretory, neuritic, neuralgic, emotional processes are all normally concerned in this still unravelled cenesthetic complex, sensory and subsensory. The mere mention of nervous dyspepsia and hysterical anorexia suggest research work for several cand. doct. phil. for years to come. Why not appreciate that such work

would base the human mind on a firmer base than ever it stood on yet?

The *urinary apparatus* constitutes in a sense part of the nutrition mechanism, but its machinery is distinct. Kidney, ureter, valve, bladder, sphincters, urethra—each has its contribution of clear or of vague sensation in the fabric underlying our empirical minds, 'conscious' or ready-to-be-conscious, that is, subconscious. The urinary bladder especially and its outlet have a rich complex of sensory neurones and its movements, active, tonic, and really passive, have no small part in the emotive life at every age. Introspective analysis here would certainly reveal data worth the having, especially if pathologic conditions, hysterical and neurotic, were included in the research to furnish exaggerations of the usual and normal contributions, and if here, as elsewhere, anesthesias, by way of negative variation, could be observed. The tonus of the urethral sphincters respectively in the two sexes plays a part in adolescent, as in infantile, consciousness and merges oftentimes into the still richer field for exploration by psychology, the reproductive mechanism.

The *genital organs*, external and internal and mammary, have been elaborately studied of late in certain of their relations to society and to criminology, but even the start in the purely cenesthetic analysis as a basis for the rich love-aspect of humanity has scarcely as yet been made. One thinks first of course of Ploss and Bartels's 'epochal' work ('Das Weib'), of Havelock Ellis's 'Psychology of Sex,' and of Moll's 'Sexual Life of the Child.' The present writer has started the cenesthetic analysis for his annual lectures in the School of Eugenics on the technical psychology of the sexual impulse. Here certainly is a rich field, hard and often disagreeable to till (the motives of the tiller often misjudged), but with material that involves more than any possible other the evolution of the mind as a social reagent. In general only the keen family physician, the really learned gynecologist, the scientific social worker, and the psychopathologist above all realize how rich this relationship is here between physiologic process and womanhood and manhood in the realest sense of these words.

The *spleen* has abundant trabeculæ of smooth muscle with known active movements of contraction, and it is proper therefore to suppose sensory or at least subconscious concomitance. It has nerve-connections with the vagus and with the splanchnics, both having afferent pathways. Distension of the capsule increases the sensorial tonus and strain until actually painful.

The *skin and mucosæ*, more than two square meters in extent, are cenesthetically as well as kinesthetically productive. These I have recently discussed somewhat in this journal.[1] The skin has the epicritic sensitivity as well as the protopathic beneath it, and contributes always a large but variable amount to the stream of consciousness, especially of course in its (intrinsic and extrinsic) environmental phases. Heat and cold, the tickle of excessive sweat and of other agents, the movement or stagnation of the air, massive friction and pressure sensations, hair-erection (reflex or voluntary), hyperemia from vasodilation,—all these and others constitute a rich complex of actual or potential consciousness.

The mucous membranes, inasmuch as simpler in structure and function than the skin, have simpler cenesthesia, but their modicum is none the less important for descriptive psychology. Let the reader for example attend a moment to the "feel" of his conjunctiva or of the back of his tongue and thus be reminded of the things familiar *always* to the subconscious bulk of his mental process.

The *epithelia*, gland-tissues, have in some cases, at least, essential part in the cenesthesia, especially in connection with their respective mucosæ, but also by themselves. For the former one cannot avoid thinking of the salivary secretion and of the genital. As for the glands themselves, the thyroid and thymus and mesenterics (Behan) have distension-sensations and pain well defined, while the adrenals furnish warning of hemorrhage by severe pain. The breasts are rich in sensations both pleasurable and painful, and are provided with many other sensations at different stages of life. Action of many of the other glands is distinctly pleasant.

[1] "Certain Further Factors in the Physiology of Euphoria," XXI., 3, May, 1914.

Pathologically, the sensory complex of the secretory system is a rich one, with always a "limit" (on one side of the affective balance) of pain.

The *osseous and connective tissues* give rise, especially the former, to numerous grades of sensation, but these, like the sensory quota of the far more important synovial membranes, are properly classed as kinesthetic, because directly motor.

In an organic afferent world thus sketchily suggested, composed of all our receptive fields, certainly there is unlimited room for raising a good quality of mind!—and the cultivators thereof will prosper.

This sensation-fabric, especially its kinesthesia, personified, made useful by relation to the environment within and without, mediately gives us the *meaning* of bodily life because it is the dynamic index in our personalities of "the world we live in." At least thirteen hundred thousand pathways, according to one count and estimate of a reliable grade, connect all these regions (through the autonomic, partly) with the spinal white or grey and there through with the great cortex; and no man knows yet and no woman can guess how many neuronal paths that more or less represent mind are part of the autonomic itself. Perhaps[1] our search for psychophysical couplers, such as neurones, is entirely superfluous anyway; personally at present I do not go so far. Besides the neurones, then, which bear influences (impulses or perhaps strains) into the cerebrospinal axis, at least seven hundred thousand (by the same count) carry messages outward from it, and it would be both pedantic and wholly unwarranted to assert that these motor influences make up no part of the process of normal mentation.

It is theoretically important to observe in passing, as further 'elaboration' of what should long since have been 'the obvious,' that this double flood of influences afferent and efferent in one way or another *involves the action of every part of the brain.* We came to the same conclusion in a discussion of voluntary movement about four years ago, and unpub-

[1] See "Consciousness in the Brutes," *J. of Nerv. and Mental Dis.*, XXXIV., 1 and 2.

lished work on the physiology of emotion and on the neurology of thought lead to the same necessity of belief.

A deep knowledge of cenesthesia would have value not only in the science of psychology, but properly developed and then properly sifted and subjugated to the hygienic requirements, it would have practical educative and therapeutic values of account to every individual, perhaps especially in its kinesthetic phases, but also in the other phases as well. Most of us have never explored even the living executive house in which we live, although to know it thoroughly (but neither too thoroughly nor too habitually) is the indispensable basis of that self-control that means personally much. Such knowledge would also be the basis of that generalized skill ever richer that means to most of us 'socially' nearly everything, for on it almost always depends a mortal livelihood. To develop, in short, a real scientific knowledge of what I have tried to make explicit as cenesthesia would be to make a man, in one sense for the first time, master of himself (if not indeed 'captain of his soul'). Then at length will motives be less blind—and perhaps virtue, as well.

But cenesthesia certainly is not mind, for an unexplained remainder intervenes between this feeling-of-being-alive and the subconsciousness. This unexplained remainder has been variously explained, but never better, because never more vaguely, than by the Sage of Königsberg as "the transcendental unity of the understanding"; perhaps were I an older convert to Animism than I am, we should read instead of this sonorous phrase simply the mind in process, or perhaps the Soul.

At any rate we have arrived at the subconsciousness, and here description becomes needless, for you all are familiar with 'The Philosophy of the Unconscious' by Eduard von Hartmann, with Morton Prince's 'The Unconscious,' and with many descriptive works between these and before. You all certainly are familiar in some way with the massive part of the stream of mind and with this part which especially gives it momentum, making it go and making it *do*. Knowledge

of all this, certified and vivified of late by the new Freudian books and the work of physiologists typified by Cannon, has been in the philosophic atmosphere for long.

One of its names in the history of philosophy is Transcendentalism, in some respects the culmination of practical philosophy up to our time. One thinks of Carlyle, of Browning, and, here in the New World, first especially of the great Emerson. Self-reliance, compensation, 'circles,' even the 'Over-soul' itself finds its expression at least in the new philosophy of the subconscious. "If we ask," says Emerson in 'Self Reliance,' "whence this ['immense intelligence'] comes, if we seek to pry into the soul that causes, all philosophy is at fault. Its presence or its absence is all we can affirm. Every man discriminates between the voluntary acts of his mind, and *his involuntary perceptions, and knows that to his involuntary perceptions a perfect faith is due. He may err in the expression of them, but he knows that these things are so, like the day and night, not to be disputed.*"

This certainly expressed the subconscious phases of the human mind and even makes explicit (in the 'involuntary perceptions') the sensational flood, the cenesthesia as index of the reactions of the organism. When one considers the height from which Emerson viewed life, as far as possible 'above' neurology and technical psychology, the evidence is still more striking.

And yet, psychologists in general are certainly not yet awake to the deep and wide implications of the subconscious, although many are dreaming of them (in their subconscious). How can one awaken them? for surely they belie not only their own breadth of mind but their science in keeping their brains, like their eyes, shut tight.

What possible sanction have they to drowsily suppose they may dream on, a dream within a dream? To do so would be comparable to the behavior of a self-taught physician if he refused to accept the infectious origin of many diseases, or to use an anesthetic in his amputations, or to recognize the therapeutic uselessness and menace of alcohol. Such a one would be himself a menace to the common welfare. But surely

the teacher of psychology who refuses to include the subconscious aspects of mind concomitant to reaction and cenesthesia is a like offender, although one far less baneful. But he is misleading his students,—a modern Sophist 'making the worse appear the better reason' for many kinds of human behavior.

Psychology is as perfectly fitted to be one of the most essential, most interesting, and most practical subjects of every grammar-school curriculum, as to be the field of research in work for the philosophic doctorate. But without the subconsciousness as a basis it cannot easily be made generally explicable.

Some of you certainly are saying, Surely each philosopher has his right to his own opinions!? I protest he has not when those opinions unduly narrow a science and deprive it of half its interest and more than half its force. None are so deaf, traditionally, as those who will not hear! Think you that some of the neurologists and the psychopathologists and the alienists are not competent psychologists because they deal partly with mind that is out of order? It is time that such mediæval crudities of distrust were outgrown.

It certainly is only by such continual and immediate reference to the body, the mind's own sister organism, that the great goal of the philosophy of mind, real explanation of human motivity, can ever be attained. Perhaps then at length our science, determinant in various degrees of all the rest, will take her rightful place as the Queen of the Sciences in the unanimous estimation of the world of men and women whom, in part, it will then really explain.

Summary

Laboratory research in psychology, much as it has done, has failed to *explain* the mental process. Far too little time has been devoted, perhaps, to understanding the immediate relations between the body as an organism, at once developer and adapter of the soul, and the mental series proper. We need much more casuistric introspection based on anatomy

and physiology; recent advances demonstrate anew the reality and urgency of this lack.

The organism by its inherent nature is ever in universal movement, movement both active and passive, and continuous both in time and in space. The (1) universal muscular tonus; (2) equilibrium; (3) reaction-basis; (4) the reciprocal innervation of functional antagonists; (5) irradiation; (6) volition; (7) reflexion; (8) mechanical respiration; (9) circulation; (10) digestion; (11) excretion, are some conspicuous topics under which this universal organic motion, always unique, might be examined into. To deny as 'unproven,' 'illogical,' etc., the immediate relation of this universal movement with mind, is little short, these days, of jugglery with the truth, denying both at once the very ground of the whole category Life and its final purpose.

Cenesthesia is the sensory and subsensory aspect of this universal bodily movement, director of the soul's important business. Its details in every portion of the organism should be known to every psychologist as the very elements of his subject. This sensation-fabric lends the meaning to life because it is in an important sense the dynamic index of our personal evolution and of our adaptation to our kinetic surroundings, both material and spiritual. Its reality is not lessened by its necessary partial *action in the dark*.

The practical educative prophylactic and therapeutic values of cenesthesia are great, but as yet are relatively undeveloped save in just the wrong direction (hypochrondria).

The new work of the psychopathologists and of the physiologists lends new dynamism to the subconsciousness, to which by integration of the cenesthesia we arrive. However much *more* it may mean, the transcendental 'over-soul' expresses this phase of the mental process.

To ignore the subconsciousness as an element of mind in one's thought, and especially in teaching, is as unsanctioned as for a physician to refuse the fact of the infectious origin of some diseases or of the menace of 'therapeutic' alcohol; it is to try, once more, to 'make the worse appear the better reason.'

Psychology is perfectly well fitted to be a popular and essential grammar-school subject.

These propositions are not yet 'massive' ideas to most psychologists, but there is great need that they become so.

It may be that only by elaborating this moto-cenesthetic relationship can psychology become really explanatory and so take her rightful place as the queen of the sciences.

MENTAL ASSOCIATION FROM PLATO TO HUME[1]

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I

The notion that one idea or memory image follows another according to certain definite principles was the first step toward a general theory of association among mental states. This fundamental notion is found first, and in quite definite form, in the writings of Aristotle (B.C. 384–322). The earlier Greek philosophers were too engrossed in the problems of objective reality to examine the processes of experience.

Plato suggests almost casually, in the *Phædo*, the function of *contiguity* and *similarity* in the act of recollection. "What is the feeling of lovers when they recognize a lyre or a garment or anything else which the beloved has been in the habit of using? Do not they from knowing the lyre form in the mind's eye an image of the youth to whom the lyre belongs? And this is recollection: and in the same way anyone who sees Simmias may remember Cebes. . . . And from the picture of Simmias you may be led to remember Cebes. . . . Or you may be led to the recollection of Simmias himself. . . . And in all these cases the recollection may be derived from things either like or unlike. . . . When we perceived something either by the help of sight or hearing or some other sense, there was no difficulty in receiving from this a conception of some other thing, like or unlike, which had been forgotten and which was associated with this."[2]

Neither here nor in the 'Timæus,' which contains a fairly broad psychology, does he develop the notion further. According to Plato, knowledge is innate; learning consists merely in drawing out such knowledge as the soul had in

[1] Part of a forthcoming volume on the history of Associationism.

[2] 'Phædo,' 73–6, Jowett trans.

previous existences. We draw out such knowledge, just as we recollect events of the present life, by means of similar experiences, or by unlike but 'contiguous' ones.

Aristotle's systematic investigation of the whole realm of things knowable led him to examine mental facts quite as thoroughly as physical phenomena, and to employ for this purpose considerable self-observation. In the course of his study he noticed that the links in chains of thought which end in the recollection of particular facts succeed one another more or less systematically, and he believed that he had discovered the principles of their connection. Only three sorts of relationship, he affirms, are involved in the succession of thoughts: similarity, contrast, and contiguity. This and his doctrine of the fusion of experiences mark the historical starting-point of Associationism.

Aristotle's analysis of the sequence of mental processes is somewhat obscure, owing partly to the physical import of many of his terms, partly to the difficulty of getting at his real standpoint and interpreting his statements into modern psychological language. There are uncertainties too in the text at critical points, and one is always in danger of reading into his elliptical phraseology a meaning which he may never have intended. Sir William Hamilton's brilliant and exhaustive discussion of Aristotle's contributions to our theme is certainly open to this last objection.

It is in treating of memory and recollection that Aristotle brings out his notion of association. "A sense is capable of receiving into itself sensible forms without their matter, just as the wax receives into itself the mark of a ring without the iron or gold."[1] The persistence of such an impression constitutes memory,[2] which is 'neither sensation nor conceptual thought but the condition or modified form of one of these after the lapse of time.'[3] "Memory is the possession of an experience potentially revivable."[4]

The problem then arises, How is such a revival, which we

[1] 'De An.,' II., Ch. XII., 1; *cf.* 'De Mem.,' I., 10.
[2] 'De Mem.,' I., 10.
[3] 'De Mem.,' I., 4.
[4] 'De Mem.,' II., 12.

call recollection, brought about? "Recollection occurs," says Aristotle, "inasmuch as one experience naturally succeeds another. If [the succession be] necessary, it is plain that when the one is stimulated it will stimulate the other; if not necessary but habitual, then it will stimulate it only in most instances. It is a fact that some persons are more habituated after being stimulated once than others after many times; just so we remember some things better after seeing them once than other things after many times. Hence, when we are recollecting we keep stimulating certain earlier experiences until we have stimulated one which the one in question is wont to succeed. And just so we hunt through the sequence, thinking along from the present or some other [thought], and from similar or contrasted or contiguous. By this means the recollection comes; for the experiences are in some cases identical with [the one in question], in others simultaneous with it, in others they involve a portion, so that the remainder is small and is thereupon stimulated. In this way, then, persons make effort [to recollect], and in this way also without effort they do recollect, when the [experience] in question succeeds some other experience; though it is generally after a succession of other experiences such as we have mentioned that the one in question comes. It is not necessary to inquire how we remember the remote, but only the contiguous; for it is plain that the procedure is the same—I mean, that of sequence—when we [recollect] without preliminary effort and even when we fail to recollect. For experiences habitually follow one another, this succeeding that. And so, when a person wishes to recollect, he will do this: he will endeavor to get some initial experience, which the one in question succeeded. Just so recollection comes most quickly and best [if it proceeds] from an initial point; for just as things are related to one another by sequence, so also are experiences; and such matters as have a regular order are easily remembered—for instance, mathematical science; others poorly and with difficulty."[1]

[1] 'De Mem.,' II., 6–11 (451*b* seq.). I am indebted to my colleague, Professor E. Y. Robbins, for assistance in this translation, which aims to go no further than

The conception of association developed in this remarkable passage covers a broader field than the mere act of recollection which it seeks to explain. Aristotle's main contentions may be restated in more modern form as follows: In accounting for recollection we should observe that it depends on the *sequence* of mental processes. Mental processes always take the form of a series, or train. Their serial association is due in some cases to a necessary connection, in others merely to their occurring together habitually. Habitual connection brings about actual association in most cases, but not always. Its power to do so varies with the individual and the sort of experience. The series may start with present experience (? sensation) or with something besides present experience. Its members follow one another according to similarity, contrast, or contiguity. The process is the same in 'efforts to recollect,' whether successful or not, as in spontaneous recollection. Usually the series or train consists of several members. After some elaboration of the last two points the author makes this practical application: Since *serial order* is the natural characteristic of mental states, we shall recollect most readily what we wish if we begin by calling up something related to it; and similarly, subjects which have a natural order of sequence, such as mathematical truths, are those most easily fixed in memory.

Aristotle's contribution to the theory of successive association, if this interpretation be correct, is fourfold. (1) He was the first to point out clearly that the sequence of cognitive experiences is not mere chance, but occurs through a definite process of natural association. (2) He recognizes habit as an important factor in determining association—subject, however, to individual variations. (3) Most important of

the text justifies. The words in square brackets are our own insertions. Aristotle's use of physical terms in discussing mental facts will be understood if we render *κίνησις stimulation*, instead of *experience;* the verb *κινέω* has been translated *stimulate*. Aristotle uses the noun, like the verb, in the sense of movement or energy, but psychologists will find 'experience' or 'mental process' quite near his meaning—and more intelligible. The text used is Bekker's edition. Compare Sir Wm. Hamilton's rendering (Reid's Works, Note D**), and the excellent translation by W. A. Hammond ('Aristotle's Psychology,' p. 204). I have followed Hammond's version in the other quotations.

all, he specifies the three principles of similarity, contrast, and contiguity as the sole bases of 'habitual' associative connection. (4) He declares that the same laws hold in purposive thinking as in the spontaneous flow of thought.

Fusion, or simultaneous association, was not altogether overlooked by Aristotle, though his discussion of this point contains more apriori reasoning than introspection. Two separate simultaneous sensations, he says, are impossible. Even with a single sense, such as vision, the stronger of two sensations will displace the weaker; or if they be of equal strength they will counteract each other, leaving no sensation at all. But if they are not separate, they may combine and a new sensation arise, fused out of both elements.[1] Much less can there be two separate simultaneous sensations from different senses, such as vision and taste.[2] But in this case also fusion may occur, as for instance between white and sweet. This variety of fusion is attributed by him to 'some unitary principle of the soul,' which senses the white and the sweet as a single unit.[3] It is interesting to note that very similar conclusions regarding fusion are reached by a set of modern writers—based, however, on quite different premises.

II

I can find no evidence that Aristotle's views on successive association were adopted or even understood by the thinkers of the centuries immediately following. In a few instances only was the problem even approached.

The psychology of the Stoics we know only at second hand. According to the summary of their doctrines given by Diogenes Laertes (ca. 200 A.D.), which is the nearest we can come to the original, the Stoics held that thoughts are formed by "similarity, or analogy, or transposition, or combination, or opposition. By a direct perception we perceive those things which are the objects of sense; by similarity, those which start from some point present to our senses; as, for instance, we form an idea of Socrates from his like-

[1] 'De Sensu,' VII., 3–4; *cf.* 7.
[2] *Ibid.*, 9, *cf.* 14.
[3] *Ibid.*, 24, *cf.* 26.

ness."[1] It is not clear whether this view was held by Zeno of Cittium, the founder of the school (B.C. ca. 342–264), or was developed by his disciple Chrysippus (B.C. ca. 281–208). The examples which are given of the other processes indicate a very superficial analysis, which does not touch the problem of the modes of association.

Epicurus (B.C. 342–270), according to the same authority, held that 'every notion proceeds from the senses, either directly, or in consequence of some analogy, or proportion, or combination.' 'The recollection of an external object often perceived anteriorly' occurs as follows: "At the same moment that we utter the word *man*, we conceive the figure of a man, in virtue of a preconception which we owe to the preceding operations of the senses."[2] The notion of successive association is certainly implied in this, but it is not clearly brought out, and no analysis of the ways and means is given in the text. Nor do the disciples of Epicurus appear to have worked out the problem further.

Among the Sceptics, Carneades (B.C. 213 ca.–129) definitely alludes to successive association. According to Sextus Empiricus, this writer compares the succession of thoughts to a chain, in which one link is dependent on another.[3]

St. Augustine (A.D. 354–430), though indebted to Aristotle, takes a different view of memory and recollection, in which he lays most stress on association by *contiguity*. Memory, he says, receives within its gates all sorts of sense impressions. "Nor yet do the things themselves enter in, only the images of the things perceived."[4] Out of this store we are continually weaving together new images of things which we have experienced (§ 14). In darkness and silence we can bring up colors and sounds (§ 13). "But what when the memory itself loses anything? . . . Where do we search but in the memory itself? And there, if one thing be offered instead of another, we reject it, until what we seek meets us;

[1] Diog. L., VII., Zeno, § 36; Bohn's trans., p. 278.
[2] Diog. L., Bk. X., § 21; Bohn, p. 435–6.
[3] Sext. Emp., 'Adv. Math.,' Bk. VII., § 176; see Hamilton's 'Reid,' p. 894.
[4] 'Confessions,' Bk. X., § 13; Parker's trans., 1885.

and when it doth, we say 'This is it.' . . . By the part whereof we had hold was the lost part sought for."[1] That the "lost part," when it is found, comes from memory, is shown by the fact that it is recognized. If we are trying to recollect a name, and some one mentions it, it comes to us not as something new, but as familiar. "Were it utterly blotted out of the mind, we should not remember it, even when reminded."[2]

Augustine limits the associations involved in recollection to relations of contiguity; the experiences reinstated are 'parts' of the experience which calls them up. But as his illustration shows, the relation of parts is not limited to mere spacial contiguity; it embraces the totality of elements in any experience. He applies the principle of contiguity in its broadest sense.

The many commentators on Aristotle during the middle ages took up the passage on recollection which I have quoted. They discussed and amplified it, as they did every saying of the master, but without throwing any new light on association. Sir William Hamilton made an exhaustive search of this literature, which he presents in the voluminous note (D**) at the end of his edition of Reid's works. In none of the authors there cited, except those already mentioned, can I find any real contribution to the doctrine up to the time of Descartes and Hobbes. It must be borne in mind that during the latter part of the middle ages to depart from the dicta of Aristotle was regarded as akin to heresy. Any freshness or originality was frowned upon; the only advances came from new interpretations—and these too often were misinterpretations. The verbal contributions to the doctrine of association during this period are minutely treated in Hamilton's survey, to which I refer the reader who delights in textual exposition.[3] A single instance will serve to illus-

[1] § 28.

[2] *Ibid.*

[3] Hamilton's citations are reliable, but not his interpretations of other writers. His criticisms are biased by his own standpoint and often reflect his prejudices. As I have already said, he reads too much into Aristotle's elliptical phraseology. I am also of the opinion that he gives altogether too little credit to Hobbes and other writers

trate the vain groping after new light at the dawn of modern times.

Luis Vives (1492–1540), a Spanish commentator on Aristotle, was at the same time a writer of some originality. Commenting on the passage which we have examined, he ventures the view that recollection occurs 'by steps,' 'from cause to effect; from the latter to instrument; through the part to the whole; from this to situation; from situation to person; from person to earlier and later things; to contrary; to similar.'[1] "On looking at a place, from this there comes into the mind what we know to have happened in the place or to be situate there."[2] He thus recognizes the broad fact that trains of thought proceed in the direction of many sorts of logical relationship; but he does not attempt to analyze these laws of association into their first psychological terms as did Aristotle.

René Descartes (1596–1650), the herald of the new era of thought, in spite of the great variety of topics which he treated, has little to say on the subject of memory and recollection. We may attribute this neglect to his doctrine of innate ideas, which made it seem to him of slight importance to explain how former experiences are 'recalled' in memory.

In his posthumous work, the 'Traité de l'homme,' speaking of the action of objects on the nerves and brain, he says: "They have the strength to form for themselves there certain passages which still remain open after the action of the object . . . has ceased, or which, if they close up, at least leave a certain disposition in the little fibers of which the brain . . . is composed, by means of which they can much more easily be opened again than if they had never been so before. . . . And also it must be noticed that if we open only certain ones . . . this of itself may be the cause of others . . . reopening

of later date. Originality consists not always, nor chiefly, in collecting the raw material; more important is the shaping of the material—the framing of a consistent viewpoint. A doctrine is not old because its elements have been used before, any more than a poem is old because previous writers have employed the same words or the same alphabet.

[1] 'De Anima,' Bk. II., ch. De Mem.

[2] *Ibid.*, Bk. I.

also at the same time, especially if they had all been opened together several times and had not been used to being so one without the others. This shows how the recollection of one thing may be excited by that of another which was formerly impressed on the memory at the same time as it."[1] "The vestiges in the brain," he says elsewhere, "render it fit to move the soul in the same fashion as it was moved before, and thus to make it remember some thing, even as the folds which are in a piece of paper or a cloth make it more fit to be folded as it was before, than if it had never been so folded."[2]

Descartes seems to hold that things which have been experienced together tend to be recalled together (contiguity), and that an experience will recall an earlier experience which partially—even though not wholly—resembles it (similarity). The reinstatement is made easier through habit, and is accomplished through the 'vestiges' of the former experience in the brain.

III

With Thomas Hobbes, of Malmesbury (1588–1679), began a new epoch in the development of the doctrine. Aristotle's work was mainly by way of enumeration and classification. He applies the laws of associative connection which he discovered to but one class of experiences—memory. Only by implication are they extended to the relations between memory, sensation, and the other mental processes. And neither the later Greeks nor the Schoolmen, neither Augustine nor Descartes, despite their independent analyses, advanced perceptibly beyond his position. Augustine merely emphasizes the law of contiguity at the expense of similarity and opposition. For Descartes the associative process signifies a connection between brain states rather than experiences.

Hobbes's psychology is noteworthy as an initial attempt (1) to establish the relation between different sorts of mental

[1] Cousin's French ed., Vol. IV., pp. 400–1. The omissions, with one exception, are letters referring to an accompanying diagram. The translations from Descartes are mine.

[2] 'Lettres,' I., 36; French ed. of 1667.

states on what we would today call a psychophysical basis; and (2) to trace all mental content ultimately to sense experience, doing away with the old notion of innate ideas. The real importance of Hobbes must be measured in the light of his influence on subsequent thought. The British thinkers who followed him developed their systems of psychology along the lines that he marked out; the notion of association, which he did little more than outline, became more and more prominent as the analysis was perfected. His historical value to associationism, therefore, lies not so much in his own contributions to the doctrine as in the fact that he established the type of psychology out of which it naturally and logically developed.

Hobbes's own standpoint is sensationalistic, rather than associationistic. He is chiefly concerned in showing that the 'cognitive powers' of the mind deal only with material given by the senses. The effect which an object produces on the brain, he says, does not cease when the object ceases to work upon us; 'though the sense [sensation] be past, the image or conception remaineth.'[1] Imagination is any 'conception remaining and by little and little decaying from the act of sense.'[2] The strongest and clearest of these images are found in dreams and in visual after-images.[3] A weaker sort is fancy, which he calls *fiction:* "The brain, or spirit therein, having been stirred by divers objects, composeth an imagination of divers conceptions that appeared single to the senses. As for example, the sense showeth at one time the figure of a mountain, and at another time the color of gold; but the imagination afterwards hath them both at once in a golden mountain."[4] Imagination in all its forms is 'nothing but decaying sense.'[5] "Imagination and memory are but one thing."[6] Expectation is of the same nature; for, 'of our conceptions of the past we make a future.'[7] Even science,

[1] 'Human Nature,' 1650, Ch. 3.
[2] *Ibid.*
[3] *Ibid.*
[4] *Ibid.*
[5] 'Leviathan,' 1651, Ch. 2.
[6] *Ibid.*
[7] 'Hum. Nat.,' Ch. 4.

the 'knowledge of the truth of propositions, and how things are called, . . . is remembrance.'[1] All the 'cognitive powers' are thus brought into relation, directly or indirectly, with sensation. "There is no conception in a man's mind which hath not at first, totally or by parts, been begotten upon the organs of sense."[2]

The succession of experiences remains to be accounted for. Sensations arise from the action of external things upon our organs,[3] and their succession requires no special psychological explanation. The sequence of imaginations is governed by sensation: "We have no transition from one imagination to another, whereof we never had the like before in our senses. . . . Those motions that immediately succeeded one another in the sense continue also together after the sense; insomuch as the former coming again to take place, and be predominant, the latter followeth by coherence of the matter moved. . . . But because in sense, to one and the same thing perceived sometimes one thing sometimes another succeedeth, it comes to pass in time that in the imagining of any thing there is no certainty what we shall imagine next; only this is certain: it shall be something that succeeded the same before at one time or another."[4]

Trains of thought are of two different sorts: (1) Such as are 'unguided, without design, and inconstant';—yet even in these, he remarks, we 'may ofttimes perceive the way of it and the dependence of one thought upon another';—and (2) those 'regulated by some desire and design.'[5] Regulated trains of thought occur, either 'when of an effect imagined we seek the causes or means that produce it,' or 'when, imagining anything whatsoever, we seek all the possible effects that can by it be produced.'[6] The sequence from effect to cause is

[1] *Ibid.*, Ch. 6.
[2] 'Lev.,' Ch. 1.
[3] 'Lev.,' Ch. 1.
[4] Ch. 3.
[5] *Ibid.* In the 'Human Nature' the trains are called 'casual and incoherent' and 'orderly' respectively. In this work also Hobbes attributes the succession of conceptions to their previous 'coherence or consequence' as sensations (Ch. 4).
[6] *Ibid.*

common to man and beast, while that from cause to effect belongs to man alone.

Hobbes thus concludes that *contiguity* in previous experience, which he terms 'coherence,' is the basis of all sorts of sequence of representations, but he finds it impossible in many cases to explain the preference of one association over another. Desire is a powerful agent in effecting the selection,[1] and so is habit.[2] Of the influence of habit on the succession of imaginations Hobbes says: "It is the nature of almost every corporal thing, being often moved in one and the same manner, to receive continually a greater and greater easiness and aptitude to the same motion, insomuch as in time the same becometh so habitual that, to beget it, there needs no more than to begin it."[3] Thus, man having invented language, "custom hath so great a power that the mind suggesteth only the first word, the rest follow habitually and are not followed by the mind."[4] It is interesting to notice that Hobbes emphasizes our lack of attention to the subsequent terms of an habitual association train, in the same passage in which he insists on the strength of the cohesion between the members.

There is only a brief allusion to fusion of images in Hobbes's writings. In the passage on *fancy* already quoted he recognizes the possibility of joining together in one imagination two images which the senses have given at different times. But he appears to regard the 'coherence' of sensations as a physical rather than a mental phenomenon.

IV

To John Locke (1632–1704) belongs the credit of originating the phrase *association of ideas*. Locke's 'Essay concerning Human Understanding' is avowedly an attempt to combat the Cartesian theory of innate ideas by showing that knowledge arises from experience alone. It was important for this purpose that he should examine thoroughly the relations between different sorts of experience and the processes by

[1] 'Lev.,' Ch. 3.
[2] 'Hum. Nat.', Ch. 5.
[3] *Ibid.*
[4] *Ibid.*

which one experience leads to another. It should be borne in mind that Locke uses the term *idea* to denote any sort of experience. He has no single term to express representative experience, to which the term idea was later restricted.

Locke distinguishes between two sources of ideas, sensation and reflection, and calls the two classes of experience that arise therefrom *ideas of sensation* and *ideas of reflection*, respectively.[1] Compared with Hobbes, he takes a more 'functional' attitude. Hobbes regards sensation as the source of all experience; the representative elements are merely corruptions of the original sense elements. According to Locke, the 'ideas of sensation' are transformed into other sorts of ideas by a separate function or faculty, which he calls reflection; and further, there are certain ideas derived from reflection alone; among the latter are the ideas of the processes of 'remembrance, discerning, reasoning.'[2]

Ideas, or experiences, are fixed in memory, he says, by *attention* and by *repetition*, but still more effectually by the *accompaniment of pleasure and pain*.[3] The reappearance of ideas as recollections is sometimes voluntary, sometimes passive. "The mind very often sets itself on work in search of some hidden idea, and turns as it were the eye of the soul upon it; though sometimes too they start up in our minds of their own accord and offer themselves to the understanding; and very often are roused and tumbled out of their dark cells into open daylight, by turbulent and tempestuous passions."[4]

Locke has little to say regarding their mode of sequence, whether by contiguity or similarity. In a passage often quoted he distinguishes between ideas that 'have a natural correspondence and connection with one another' and 'another connection of ideas wholly owing to chance or custom.'[5] It would not be difficult to resolve the former connection into similarity and the latter into contiguity. But Locke does not take the step. Elsewhere he says: "There comes

[1] 'Essay,' 4th ed., 1700, Bk. II., Ch. 1, § 24.
[2] *Ibid.*, Ch. 6.
[3] Ch. 10.
[4] Ch. 10, § 7.
[5] Bk. II., Ch. 33.

by constant use to be such a connection between certain sounds and the ideas they stand for, that the names heard almost as readily excite certain ideas as if the objects themselves which are apt to produce them did actually affect the senses."[1] This again implies association by contiguity, but Locke's purpose in the discussion is only to emphasize the strengthening effect of habit. Nowhere does he name or formulate the principles of the sequence of ideas, as Aristotle did.

On the other hand, Locke makes much of the phenomenon of simultaneous association, though his contributions to this phase seem to have been generally overlooked. The mind exerts its power over its simple ideas, he says, chiefly in three ways: (1) 'Combining several simple ideas into one compound one,' which gives us our *complex ideas*. (2) 'Bringing two ideas, whether simple or complex, together, and setting them by one another, so as to take a view of them at once, without uniting them into one,'—which gives us *ideas of relations*. (3) 'Separating them from all other ideas that accompany them in their real existence; this is called abstraction,' and is the means by which all our *general ideas* are formed.[2] These processes correspond closely to our modern conception of fusion, complication, and analysis.

The unity of the complex idea arises "from an act of the mind, combining those several simple ideas together, and considering them as one complex one consisting of those parts," even where they do not exist together in nature.[3] "All our complex ideas are ultimately resolvable into simple ideas, of which they are compounded and originally made up, though perhaps their immediate ingredients . . . are also complex ideas."[4]

In another passage Locke gives the name of *composition* to the operation whereby the mind 'puts together several of those simple ideas it has received from sensation and reflection, and combines them into complex ones.'[5] "As simple

[1] Bk. III., Ch. 2, § 6.
[2] Bk. II., Ch. 12.
[3] Ch. 22, § 4.
[4] *Ibid.*, § 9.
[5] Ch. 11, § 6.

ideas are observed [by the senses] to exist in several combinations united together, so the mind has a power to consider several of them united together as one idea; and that not only as they are united in external objects, but as itself has joined them together."[1] "The mind . . . arbitrarily unites into complex ideas such as it finds convenient; whilst others that have altogether as much union in nature are left loose, and never combined into one idea, because they have no need of one name. It is evident, then, that the mind, by its free choice, gives a connection to a certain number of ideas, which in nature have no more union with one another than others that it leaves out."[2]

In view of this rather extended discussion of simultaneous association, it appears certain that Locke had in mind the coëxistence as well as the sequence of ideas when he wrote the historic chapter on Association.[3]

According to Locke's view association, whether concerned with the succession of ideas or their composition into complex experiences, is of two sorts: it is based either on their 'natural correspondence,' or on 'chance or custom.' The latter sort may be voluntary or involuntary, and is that which leads us into all kinds of error in thinking. The fact of association, the union or nexus between different experiences, though an important factor in his psychological analysis, is not the chief factor in his psychology, since it shares the field with other fundamental principles. Yet it requires only a little deeper analysis of his material to bring out explicitly the laws of similarity and contiguity.

Locke seconds Hobbes's attempt to derive all complex experience from simple experience, but differs with him in deriving simple experience from reflection as well as from sensation. He thereby abandons the field of pure sensationalism; and in this respect he is followed by later English writers. His chief historic merit in psychology, however, is his contribution of the term *association of ideas*, which focused the attention of future thinkers on this factor as a means for

[1] Ch. 12, § 1.
[2] Bk. III., Ch. 5, § 6.
[3] Bk. II., Ch. 33.

the empirical derivation of knowledge. His emphasis of habit or custom as a factor in association also had considerable influence in determining subsequent analysis.

V

Bishop George Berkeley (1685–1753) lays considerable stress on the associative process, which he terms *suggestion*, and enumerates several of its modes. "Distance," he says, "is suggested to the mind by the mediation of some other idea, which is itself perceived in the act of seeing."[1] "That one idea may suggest another to the mind, it will suffice that they have been observed to go together, without any demonstration of the necessity of their coëxistence."[2]

Berkeley divides our mental content into ideas of sense and ideas of imagination. "The ideas of sense are more strong, lively, and distinct than those of the imagination; they have likewise a steadiness, order and coherence, and are not excited at random . . . but in a regular train or series."[3] The ideas of imagination "are more properly termed ideas or images of things which they copy or represent"[4]—a hint toward our modern use of the term *idea*. "I find I can excite ideas in my mind at pleasure."[5] I can "by an act of my will . . . form a great variety of them and raise them up in my imagination," though "these creatures of my fancy are not altogether so . . . permanent as those perceived by my senses."[6] "We perceive a continual succession of ideas [both of sense and of imagination]; some are anew excited, others are changed or totally disappear."[7] The ideas themselves are inactive, 'so that one idea cannot produce or make any alteration in another,'[8] but the changes are caused by an 'incorporal active substance or spirit.'[9]

[1] 'New Theory of Vision,' 1709, § 16; cf. 'Principles of Human Knowledge, 1710, § 43.

[2] 'New Theory,' § 25.

[3] 'Princ.,' § 30.

[4] § 33.

[5] 'Princ.,' § 28.

[6] 'Dialogues between Hylas and Philonous,' 1713, II.

[7] 'Princ.,' § 26.

[8] § 25.

[9] § 26.

The succession of one sensation to another is attributed by Berkeley to Deity;[1] while the succession of a representation to a sensation is due to habitual coëxistence; 'from a frequently perceived connection, the immediate perception of ideas by one sense suggests to the mind others, perhaps belonging to another sense, which are wont to be connected with them.'[2] The same is true of the succession of one representation to another: "In certain cases a sign may suggest its correlate as an image, in others as an effect, in others as a cause. But where there is no such relation of similitude or causality nor any necessary connection whatsoever, two things by their mere coëxistence, or two ideas merely by being perceived together, may suggest or signify one the other."[3] The modes of association of successive ideas, then, according to Berkeley, are similarity, causality,[4] and coëxistence or contiguity. Like Locke, Berkeley emphasizes the pedagogic side of association: "To the end their use be permanent and universal, these combinations must be made by rule and with wise contrivance."[5]

The fact of simultaneous association is also brought out in Berkeley's writings. "A certain color, taste, smell, figure, and consistence, having been observed to go together, are accounted a distinct thing signified by the name apple; other collections of ideas constitute a sky, a tree, a book, and the like sensible things."[6] And "men combine together several ideas apprehended by divers senses at different times or in different circumstances, but observed, however, to have some connection in nature either with respect to coëxistence or succession; all which they refer to one name and consider one thing."[7] That is, the contiguity of sensations is the basis of the simultaneous association of ideas.

Berkeley's work transformed the problem of knowledge

[1] § 30.

[2] 'Dial.,' I.

[3] 'Theory of Vision Vindicated,' 1733, § 39.

[4] 'Causality or some other necessary connection if there be such,' seems to be his meaning.

[5] 'Princ.,' § 65.

[6] 'Princ.,' § 1.

[7] 'Dial.,' III.

into a distinctively psychological one. Although his philosophical standpoint is idealistic, it rests on experience, and his analysis is more thoroughly empirical than that of Locke and Hobbes. His theory of visual space perception especially called attention to the fact that our knowledge of distance away from the eye is capable of resolution into simpler experiences; and this led his successors to go deeper into the analysis and synthesis of all classes of experience. That his idealistic metaphysics affected the trend of English thought comparatively little, while his psychological empiricism exerted so great an influence, would lead us to regard the psychological side of his theory as more important historically than the philosophical side.

VI

David Hume (1711–1776) was the first after Aristotle to attempt a thorough classification of the modes of association. Indeed, he claims for himself entire originality in this field. "Though it be too obvious to escape observation," he says, "that different ideas are connected together, I do not find that any philosopher has attempted to enumerate or class all the principles of association—a subject, however, that seems worthy of curiosity. To me there appear to be only three principles of connection among ideas, namely, *resemblance*, *contiguity in time or place*, and *cause or effect*. . . . That this enumeration is complete . . . may be difficult to prove to the satisfaction of the reader, or even to a man's own satisfaction. All we can do, in such cases, is to run over several instances, and examine carefully the principle which binds the different thoughts to each other, never stopping till we render the principle as general as possible. The more instances we examine, and the more care we employ, the more assurance shall we acquire that the enumeration which we form from the whole is complete."[1] Whether Aristotle's classification was unknown to Hume, or was considered by him a mere casual list like Berkeley's, we can not be sure.

[1] 'Enquiry Concerning Human Understanding,' 1748, § 3; *cf.* 'Treatise,' Bk. I., Pt. I., § 4.

But it seems probable that Hume was not aware of Aristotle's attempt.

A significant contribution also, though only a verbal one, is Hume's alteration of the meaning of the term *idea* in the direction already suggested by Berkeley. Hume divides experience into *impressions* and *ideas*. Impressions consist of sensations, passions, and emotions 'which enter with most force' into consciousness.[1] Ideas are 'faint images of these' (*l. c.*); they are 'copies of our impressions.'[2] Ideas are of two sorts: memories and imaginations; the former are more lively, while the latter are not restricted to the order or form of our original impressions.[3]

Having settled his terminology, Hume proceeds to consider the nature of the connection between successive ideas. "It is evident," he says, "that there is a principle of connection between the different thoughts or ideas of the mind, and that in their appearance to the memory or imagination they introduce themselves with a certain degree of method and regularity."[4] "Were ideas entirely loose and unconnected, chance alone would join them."[5] But since 'the same simple ideas . . . fall regularly into complex ones,' we must suppose 'some bond of union among them, some associative quality by which one idea naturally introduces another.'[6] "This uniting principle among ideas is not to be considered as an inseparable connection. . . . Nor yet are we to conclude that without it the mind cannot join two ideas. . . . But we are only to regard it as a gentle force, which commonly prevails."[7] It is at this point in the discussion that he enumerates his three modes of association—resemblance, contiguity, and causality.

The most interesting part of Hume's subsequent analysis for our purpose is his attempt to reduce the relation of

[1] 'Treatise on Human Nature,' 1739, Bk. I., Pt. I., § 1.

[2] 'Enquiry,' § 2.

[3] 'Treatise,' Bk. I., Pt. I., § 3. Impression as used by Hume includes what are today known as sensations and percepts; his term *idea* includes both images and ideas.

[4] 'Enq.,' § 3.

[5] 'Treatise,' *l. c.*, § 4.

[6] 'Treatise,' *l. c.*

[7] *Ibid.*

causality to an habitual experience of contiguity; for in the end Hume finds no justification for the conception of a 'necessary' relation of phenomena, such as the idea of causality ordinarily implies; the notion of a necessary connection, which Berkeley insisted upon, is based, according to Hume, not on knowledge or scientific reasoning, but on observation and experience.[1] The so-called causal connection, therefore, resolves itself into a mental relation: "reason can never show us the connection of one object with another, though aided by experience and the observation of their constant conjunction in all past instances."[2] The mind, therefore, in its passage from one idea to another, is determined not 'by reason, but by certain principles which associate together the ideas of these objects and unite them in the imagination.'[3] The belief in causation, and indeed the belief of the existence of objects, is 'a lively idea related to or associated with a present impression.'[4] The three principles which he adopts from Berkeley thus reduce to two: resemblance and (customary) contiguity in experience.

Hume makes only brief allusions to simultaneous association. Among the effects of the 'union or association of ideas,' he says in the 'Treatise,' 'there are none more remarkable than those complex ideas which are the common subjects of our thoughts and reasoning, and generally arise from some principle of union among our simple ideas.'[5] In the 'Enquiry' the reference is still more vague: "Nothing is more free than the imagination of man; and though it cannot exceed that original stock of ideas furnished by the internal and external senses, it has unlimited power of mixing, compounding, separating, and dividing these ideas."[6]

Throughout his two works Hume concerns himself particularly with the association of representative experiences. But in one place he notes that "there is an attraction or

[1] 'Treat.,' Bk. I., Pt. III., § 3.
[2] *Ibid.*, § 6.
[3] *Ibid.*
[4] Pt. III., § 7.
[5] Bk. I., Pt. I., § 4.
[6] § 5.

association among impressions as well as among ideas; though with this remarkable difference, that ideas are associated by resemblance, contiguity, and causation, and impressions only by resemblance."[1] This is a mere casual statement however, and does not belong to his general analysis, which lags behind Hobbes and Locke in this respect. He alludes to an *association of voluntary acts* in the same casual way.[2] Had he brought these concepts into vital connection with the rest of his work, his psychology would undoubtedly deserve to be classed as associationism. But it was reserved for Hartley to extend the principle of association systematically to all classes of mental phenomena.

The psychology of Hume is a rounding out of Berkeley's and Locke's. Starting, like them, from the empirical standpoint, he employs a more rigid method, especially in analyzing the notions of causality and necessary connection, and advances to the epistemological conclusion that all knowledge is knowledge of experiences, and that the relations of 'things in themselves' can never be known.

Historically, his work forms the starting-point of two widely distinct movements in philosophy and psychology. The influence of Hume transformed the dogmatic attitude of the earlier German school into a critical one; Kant and his successors were impelled thereby to seek in experience some validation of the deductions of reason. On the other hand, the British school, which had already abandoned the notion of innate ideas, sought by further analysis of consciousness in terms of association to obtain the utmost out of experience. In England, philosophy after Hume became *associationistic* as well as *psychological;* while the Scottish school, inaugurated by Thomas Reid, followed Hume in the empirical analysis of consciousness, but held that experience gives a direct, intuitive knowledge of things; hence it found less need for the principles of association. In the line of direct development, Hartley's analysis is a natural extension of Hume's; but the publication of his chief work followed

[1] 'Treat.,' Bk. II., Pt. I., § 5.
[2] *Ibid.*, Bk. II., Pt. III., § 5.

closely after Hume's 'Treatise' and was partly anticipated in an earlier article. We must therefore attribute to the influence of earlier writers much of the initiative for Hartley's elaboration of the associative laws.

VII

One other writer should be mentioned before we pass to Hartley. John Gay (1699–1745), a clergyman and cousin of the poet of like name, sought to derive the moral principles from association. His work appeared anonymously in 1731, as a prefatory essay to the English translation by Edmund Law of Archbishop William King's 'Origin of Evil'; it was entitled 'Dissertation on the Fundamental Principle of Virtue,' and was acknowledged as Gay's in the fourth edition. In this 'Dissertation' our motives to action are attributed to pleasure and pain—man 'pursues the former and avoids the latter.'[1] The aim being happiness, the course of action is regulated by the "association of ideas" of pleasure or pain[2] and these associations lead to "habits."[3] That which man 'apprehends to be apt to produce pleasure, he calls good and approves of.'[4] Good and evil acts, even in the imagination, 'have a present pleasure and pain annexed to them, proportionable to what is apprehended to follow them in real existence';[5] and certain things become 'so tied together and associated in our minds' with pleasure or pain, that one can not present itself but the other will occur; and the association remains even after that which at first gave them the connection is quite forgot.[6] Some of these associations are not original, but are learned 'by imitating those whom we admire.'[7] Gay's theory was the direct precursor of the utilitarian movements in ethics.

In 1747 appeared another short anonymous work, entitled 'An Enquiry into the Origin of the Human Appetites and

[1] § 3; p. xxii, ed. of 1731.
[2] P. xiv.
[3] *Ibid.*
[4] § 3, p. xxii.
[5] *Ibid.*
[6] § 4; pp. xxx–xxxi.
[7] P. xxxiii.

Affections, shewing how Each Arises from Association,' which has been attributed to Gay,[1] with what authority I am unable to say. The views which it advances may well have been Gay's, but the frequent references to Gay's 'Dissertation' are entirely impersonal (*e. g.*, § II., 26; VI., 22). Among the positions taken in this 'Enquiry' the following may be noticed. (1) *Inseparable union:* "The joint appearance of two or more ideas frequently in the mind is for the most part changed into a lasting and sometimes an inseparable union";[2] this is illustrated by the child's hearing the sound of the word *nurse*, and at the same time seeing the nurse.—(2) *Necessary connection:* "There seems to be a necessary correspondence or connection betwixt some ideas and others."[3] Thus the ideas of space and time 'associate themselves with and are inseparable concomitants of all others';[4] the ideas of husband and wife are a 'natural' association, etc.—(3) *Coalescence of ideas:* 'When two or more objects at the same time strike the same or different organs, if the impressions are again and again repeated the ideas they excite will coalesce and unite.'[5] The author also repeats the view given in the 'Dissertation' that some of our associations 'we learn from imitation.'[6] He calls attention to the decrease of pleasure and pain by repetition of the experience. The latter part of the 'Enquiry' is an application of association to ideal pleasure and pain and to the principles of morality.

[1] Reprinted, 1837, by Samuel Parr in the 'Metaphysical Tracts'; the latter were printed after Parr's death, and the publisher found no clue to the authorship of the 'Enquiry.'

[2] § II., 18.

[3] § II., 41.

[4] *Ibid.*

[5] § II., 41.

[6] § II., 43.

THE EFFECT OF HIGH RESISTANCE IN COMMON NERVE PATHS

BY S. BENT RUSSELL

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In the study of intelligent behavior we find that the field ranges from the comparatively simple to the exceedingly complex. For the simpler forms of behavior explanations in terms of nervous mechanisms are generally admitted. As we advance towards the complex, however, we find that authorities diverge more and more and also that there is, as we so advance, an increasing tendency to explain behavior in terms belonging to the subjective aspect, as it were. From one point of view this tendency is a decided obstacle to general progress. In the study and discussion of behavior showing a high degree of intelligence, if we can formulate rational theories of nervous mechanisms, it will help us break away from the methods of subjective psychology.

There are learned men who believe that the key to an understanding of mental growth will be found in the changes that occur in the relative conductivity of the nervous fibers that connect the receptors and effectors of the body. These fibers are to be viewed as competing pathways.

In this article we shall have to consider cases where the competing paths are many in number as well as those in which they are few. It is our purpose to discuss some suggestions as to the effect of local resistance in such nerve paths upon the control of discharges, and thus indicate the nature of certain nervous mechanisms.

To begin with let us briefly consider how nervous pathways are constituted. Each path is made up of two or more neurones (nerve cells) in relays like a linked chain. Each link of the chain is a neurone and the discharge of each neurone excites the next in relay. A single neurone, however, on the one hand may have several tributary neurones, or on the

other hand it may be tributary to several neurones. The junction of each neurone with the next is known as a synapse. Just how the impulse is conducted through the chain of neurones is not well understood.

One writer of a book on psychology states:[1] "The course of an impulse through the cortex is largely controlled by synapses that owe their degree of resistance to the frequency with which they have been used. . . . The change that comes with action is a lessened resistance at the synapse. . . . The formation of habits is thus a process of decreasing the resistance of the synapses in the different possible paths of transmission."

To fit with these ideas we must allow that the impulse is divided among the possible paths, a large discharge going where the synapse is open and a small discharge where it is not open. This must be so, for it is by repeated small discharges that the resistance is decreased.

In our demonstration we may assume that an impulse leaving a receptor has several different possible paths of transmission. At some point in each of these paths we may assume there will be a nerve junction of relatively high resistance. The rivalry between these resistance points is what determines which path will be taken by the larger impulse at any given time. We may assume also that each resistance point has a resistance that varies with the frequency and recency of prior discharges. For convenience in discussion, let us term such a point of high resistance an outpost junction. Let us fix it in our minds that the impulse travels along its several paths, encountering very little resistance until it reaches the outpost junctions. It then selects the junction offering the lowest resistance at the time and the main discharge follows the course thus chosen to some motor or effector terminal.

We see that a given receptor might have a large number of outpost junctions. On the other hand, we see that for a given outpost junction there may be other (private) paths coming from other receptors. Suppose then that an impulse reaches

[1] Pillsbury, W. B., 'Essentials of Psychology,' New York, 1912, pp. 50–55.

an outpost junction coming from the first receptor which we will call *S A* and finds the resistance low. The impulse will pass on to a certain effector *M A*. Suppose also that another time an impulse comes from a second receptor *S S* to the same outpost junction and finds the resistance low. Again the impulse will pass on to *M A* and the result at the effector will be just the same as if *S A* had been excited. In other words this outpost junction lies on a path that is common to the two receptors *S A* and *S S*. Furthermore from our premises this outpost junction controls the common path in question. It is plain that every time there is excitation at *S A* or *S S* there will be some discharge that will reach *M A* and that the discharge will be great or small depending upon the openness of the junction compared with the openness of rival outpost junctions, so to speak. It is also clear that the openness or lowness of resistance at this particular outpost junction, which we will call *X*, is dependent upon the number and recency of excitations at *S A* and *S S*.

Let us now suppose that *S S* commands a hundred outpost junctions and that at first they are of equally high resistance. Now if there be an excitation of *S A* followed shortly by one of *S S*, the largest discharge from the latter will be through *X* to *M A*, because that junction has just been opened by the impulse from *S A*. So we have here a mechanism by which the excitation of one receptor influences the response from another receptor. It is a very simple mechanism, but it is thought to be adequate to account for the selective distribution of nervous impulses.

The outpost junction may be located at a synapse of some connecting neurone. The connecting neurone which is commanded by both receptors and which ends in junction *X* may be termed an association neurone. The reader may prefer to think of the association neurone rather than the outpost junction as the determining factor in associative memory.

If every one of the outpost junctions commanded by receptor *S S* is also connected with one or more other re-

ceptors, we may have a joint mechanism such that the excitation of *S S* will produce a response in any one of a hundred different effectors if the right receptor has been more recently or frequently excited. The function of this joint mechanism may be termed the selective distribution of nervous impulses.

When we say that the meaning of a certain word has to be judged by the context, we might better express the case by saying that the response to the excitation of a certain group of receptors depends upon what other receptors have been lately stimulated. The proper selective mechanism, of course, must be there.

Let us fix it in our minds that an important feature of these mechanisms is that there is low resistance from the receptor to some point in a common path and at this point there is high resistance. This relatively high resistance in the common path compared to the resistance of the private path is, so to speak, an essential factor.

It should, of course, be remembered that such a unit mechanism as we have outlined does not in reality act alone but always in concert with other unit mechanisms. The least change in the environment means the excitation of many sensory neurones and the resultant nervous discharge to the effectors determines the response.

As an illustration of the functions of these selective mechanisms, let us think of a trained animal. The setting of the stage supplies a series of impulses that arouse certain association neurones. When the trainer gives the signal the animal performs his act. When the stage setting is changed, he will at the signal do a different trick, because other association neurones have been aroused. In each case the sight of the stage properties excites impulses that arouse a certain set of association neurones and therefore open a certain set of synapses commanding nervous pathways appropriate to the performance.

In the mechanisms that we have been considering the rule is that the impulse from one private path opens the way for an effective impulse from another private path. Let us

now inquire into mechanisms that have a similar structure but a somewhat different function. If two receptors have a common path of such degree of resistance that at first the discharge through it is ineffective, but after each time that the receptors are excited consecutively the resistance of the controlling synapse is greatly lowered, a useful structure is provided. It is evident that the path will become open for an effective discharge from either receptor. If the path leads to an effector only reached in the first place by effective impulses coming from the first receptor which we will call *S* 1, while afterwards it is reached also by effective impulses from the other one which we will call *S* 2, the latter receptor is given new power. On further consideration we see that the arrangement provides for associative memory.

It must be noted, however, that a unit mechanism of this sort should have only two tributary receptors, so that the development of the mechanism depends strictly upon the excitation of the two in conjunction. In this way we get a true correspondence of the nervous development with the environment. The pathway must be common to two private paths only.

The functions of nervous mechanisms of this class depend upon the system of effector connections, as it were. With an appropriate system, the mechanism will provide for substitution as it is called, *i. e.*, where one signal comes to take the place of another in provoking a given response.

We may illustrate this case by the example of an animal that runs to the feed box when it hears the keeper coming with feed. An auditory signal has become substituted for the visual signal that is to follow.

On consideration we now see that a synapse mechanism of the type described herein will serve in one case for the selective distribution of impulses and in the other case for the linking of one impression with another in the formation of habits. We recall that the essential features of such a mechanism are low resistance in the private path coming from the receptor and relatively high resistance in the synapse commanding the common path. In other words, local re-

sistance in nerve paths will serve to control nervous discharge, and a useful arrangement of connecting nerve paths with appropriate points of resistance constitutes a nerve mechanism.

It is clear that by the concerted action of such mechanisms is made intelligent behavior, *i. e.*, behavior determined by individual experience.

DISCUSSION

ON COLOR THEORIES AND CHROMATIC SENSATIONS

BY CHRISTINE LADD-FRANKLIN

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A recent issue of the Cambridge Psychological Library—a book on 'Color Vision' by Dr. Parsons—is so good in itself and so well adapted to bringing to the fore the crucial difficulties of the Helmholtz and of the Hering color hypotheses that it invites extended discussion. It is not to the physicist and to the follower of Helmholtz that the book is especially calculated to be beneficial; they —alas!— will be too apt to be confirmed in the present error of their ways, for the psychological point of view, which demands explanation of the yellowness of yellow and of the whiteness of white, is a point of view which Dr. Parsons attains to only fleetingly and superficially. Nevertheless, the space which is given to the work of Hering, and the recognition of the widespread acceptance accorded to his views, will perhaps have a subconscious effect in laboratories where his name and his splendid fight for the psychology of color are practically unknown. It is to the adherents of the other school —the followers of Hering—that the book is destined to be invaluable. It is an attractive piece of book-making—a fact of no little importance; it is freely provided with diagrams—which act as *aide-memoires* far better than columns of figures, and which are not, in this instance, like the diagrams of Hering, free-hand drawings based purely upon the imagination; and it offers a thoroughly well-informed and acutely criticized summing up of the facts regarding color-sensation, especially those facts which have their origin in the laboratories where Helmholtz is still followed, and which are therefore *res non gratæ* to too many of the psychologists. Hereafter (on account especially of the evident effort at fairness of this book) it will not be possible for the facts which plainly contradict it to be utterly ignored in the schools where the Hering theory is made a matter of religious faith. (I am personally particularly glad to welcome so strong a defender of some of the doctrines which I have long been preaching.)

In order to obtain clearness of vision in the present situation as it regards the visual sensations, it is necessary to keep constantly in mind the sharp distinction between the Helmholtz *theory* and the Helmholtz *facts*—the facts which are supposed to support it. The Helmholtz theory has very properly long ceased to be an existent thing in the mind of the psychologist, but he has too often made the mistake of throwing away the baby with the bath,—the mass of facts which have issued from the Helmholtz laboratories are held by him in as bad odor as the theory itself. These facts group themselves, in good part, about the so-called 'color'-triangle, and the extent to which it has been of recent years possible to ignore them is evidenced by the circumstance that the very existence of the color-triangle has been, in certain laboratories, practically forgotten. But this is a great mistake; there is no necessity for ignoring these facts; it is perfectly possible to conceive of them as compatible with the great discovery of Hering (re-discovery rather—the fact was never doubted from the time of Leonardo da Vinci until the coming in of the Young-Helmholtz fallacy), namely, the tetrachromatism of the visual sensations and the independence of the sensation of

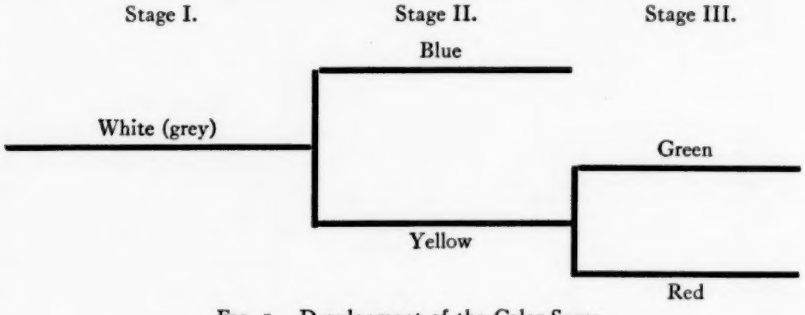

FIG. 1. Development of the Color-Sense.

whiteness. It was, of course, expressly for the sake of taking account of *both* these sets of facts, supposed by their respective defenders to be irreconcilable with each other, that I was forced, some time ago, to devise a different hypothesis—a conception which not only takes them both in, but which also accounts, at one blow, for the fundamental mystery of vision—the vanishing of the opposite color-pairs—and for the fact that the development of the color-sense is by way of a middle stage of blue and *yellow* (the poor unowned color of the physicist) (Fig. 1). In other words, this theory, the Development Theory, harmonizes and unifies, by means of a single,

simple hypothesis, these four things: the 'color'-triangle (what should be called the three-stimuli triangle or the three-receptor triangle—Fig. 2), tetrachromatism, complementation, and color development. My theory, in fact, succeeds in being, like that of Helmholtz, a three-stimuli theory, at the same time that it is, like that of Hering, a theory of tetrachromatism. The main value of Dr. Parsons's book lies in its forcible presentation of the three-stimuli view (which the followers of Hering are obliged to absolutely ignore), but he has not got psychological considerations sufficiently in the blood to perceive how indispensable it is to adhere to a theory which *unites* with that view the fact of tetrachromatism. I have discussed this aspect of my theory elsewhere.[1] That Dr. Parsons feels the necessity of having some adequate theory in terms of which to express the vastly complicated facts of vision is evidenced by his devoting the last hundred pages of his book—a little more than a third of it—to the explicit discussion of color theory (what ought rather to be called color hypothesis). It is, indeed, a disgrace that the two rival older theories should still have each its ardent defenders, who are incapable of seeing that the views which they uphold, respectively, have been again and again wholly annihilated by the party of the other part. They may be said to parallel the two forms of color blindness, each incomprehensible to the other, where one set of defectives is able totally to ignore the existence of red and green, the other the existence of blue and yellow. But it is to be hoped that this book of Dr. Parsons will have the effect of forcing each party to recognize the existence of the other,—of bringing the rivals to grips. Certainly no college professor, whether in physics, in physiology or in psychology, can hereafter lecture to his students on color without being aware that this fatal volume may easily be in their hands.

Dr. Parsons professes to give in the first and second parts of his book an account of facts only, and to treat theoretical considerations (together with such facts as are closely bound up with theory) only in Part III. This is, of course, an illusion. The two theories which he has chiefly in mind have each its own language, and no one can write, or speak, for five minutes on the subject of color without giving away that he does or does not accept certain of the fundamental assumptions of one or of the other. Thus the view of Hering that the subjective intensity of, say, a whitish bluish green is due solely

[1] See *Mind*, 1892; 'Dict. of Phil. and Psychol.,' Art. *Vision;* 'Am. Encyc. of Ophthalm.,' 1913, Art. *Color Theory*, etc.

to the subjective intensity of its whiteness component, either is or is not a part of the speaker's mental furniture. This curious view of Hering's is, of course, a consequence of his having adopted the belief that the vanishing chroma-pairs, say yellow and blue, are antagonistic instead of white-constitutive. The chromatic sensations certainly vanish, and white appears in their stead: that they vanish may, in the first instance, just as well be supposed to be due to their having annihilated each other (as for instance an oxidation and a reduction would do) as to anything else. But whence comes the substratum of the sensation of whiteness which takes their place? Either it is a residual matter, left behind, and present already in the blue and the yellow separately, or it is something which is constituted out of the processes of the blue and the yellow (just as, if there happened to be present at once an acid and a base, a salt would be formed and the acid and the base would both disappear). The destruction view looks good enough, at first sight, for yellow and blue—already it excites question for red and green, because those colors are not white-constitutive but yellow-constitutive. (It is for this reason that the physicist—a lover of truth—has never been able to give a moment's consideration to the theory of Hering.) But the strain upon one's powers of belief when one is asked to think that all the intensity of say a wholly saturated red is due to the intensity of its whiteness component, when there is no reason to suppose that it has any whiteness component whatever, is certainly very great. Dr. Parsons is of course not capable of this logical *tour de force*, and it is only the fact that he cannot really, even for a moment, think himself out of the common sense view that brightness is brightness, that enables him to imagine that he is not committed against all the vagaries of Hering from the beginning. In spite of this practically unavoidable illusion, however, he has succeeded in giving to his book a very commendable aspect of fairness.

Dr. Parsons's work exemplifies in a striking degree what I have elsewhere insisted upon—that the hopeless *impasse* that exists regarding color would be in a great measure obviated if we were to adopt a more accurate terminology.[1] What I have proposed is, in part, that the term *color*, now hopelessly ambiguous, should be used rigidly in that one of its two present senses in which it *includes* the achromatic sensations, and that for the sensation of color proper we should use the term chromatic sensation, or, simply,

[1] *Psychol. Bulletin*, February, 1913, abstract of paper on 'Color Terminology.'

chroma. (We should then have the terms chromaticity and achromaticity for 'degree of saturation' and 'degree of non-saturation' respectively.) Toned and toneless colors (the Hering terms) are also perfectly correct.—Physical light rays should not be said to be red, green, etc., but to be erythrogenic, chlorogenic, leucogenic, etc. They get their color only *after* they have been passed through the retinal receiving station.—Instead of 'brightness' (made wholly ambiguous by Hering's use of it) *subjective intensity* should, at least at present, be used, or even, for the sake of freshness, the term of Hess, *lamprosity.*

As regards the term *color,* since language affords us the two terms uni-color and monochromatic—color and chroma—of Latin and of Greek origin, why should we not at once particularize their meaning? To *préciser* the meaning of superfluous words is to secure progress in accuracy of speech, and in this case nothing could be simpler than to use *color* regularly in its extended meaning, and *chroma* for the specific meaning, color proper (as is done in real life). There is no *color* theory which does not include a discussion of the achromatic sensations. Is it not an absurdity to say, in the present loose meaning of the terms (as is constantly done in this book), that the sensations of the totally *color-blind* are *monochromatic?* The light sensations of the defective in question (and of the normal individual under various special conditions) are of one *color* only, it is true—the quality of the spectrum is white, in such cases, throughout its whole extent; but they are not monochromatic—no chromatic quality is perceived at all, but only an achromatic one.

But the real seriousness of a defective terminology occurs in connection with the discussion of the facts which are represented diagrammatically in the so-called 'color'-triangle. These facts and their significance are given their proper importance in this book, but they would be far less open to misconception if the language in which they are expressed were more carefully guarded.—To mention, preliminarily, a minor criticism in connection with this topic, it is a pity that the two triangles which are represented in diagrams (pp. 39, 40) are differently drawn about an axis of symmetry—this obscures their resemblance, to the cursory reader. In fact, the color triangle, no matter how it is laid down by the original experimenter, ought always to be drawn about the yellow-blue line as an axis of symmetry (Fig. 2), in this way is made patent to the eye the uniqueness of the *R Y G* side of the triangle, the fundamental character of yellow-blue vision, and also the peculiar mode of development of

the color-sense,—the primitive character of the color system: yellow, whitish yellow, white, bluish white, blue. Thus on the line *Y W B* are represented *all* the yellow-white-blue sensations of the red-green blind of either type; and the "confusion" colors (so

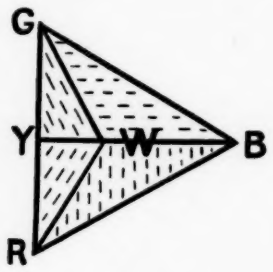

FIG. 2, *a*.

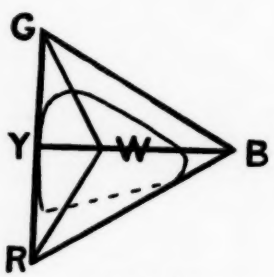

FIG. 2, *b*.

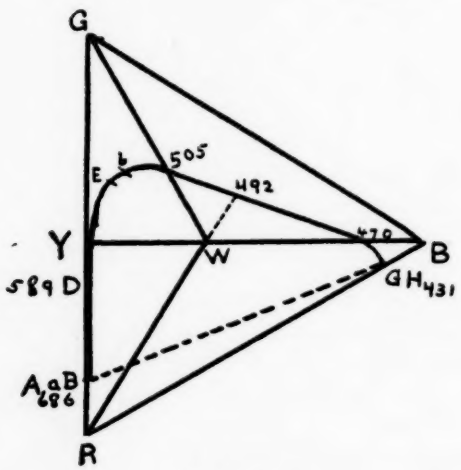

FIG. 2, *c*.

FIG. 2. The So-called "Color-Triangle," quadrigeminal in character to represent tetrachromatism, but triangular in shape as expressing the facts of matching by light-ray mixtures. The chromatogenic radiations are here represented, in trilinear coördinates, as functions of three independent variables.

mysterious to those who bother with the Holmgren wools) are one and all depicted upon lines which pass through the points *R* and *G* respectively and cross the line *Y B*.[1] Hence the convenience of making the line *Y W B* a conspicuous line in the figure is apparent.

The pivotal statement in Dr. Parsons's book, about which his

[1] See 'Diction. of Philos. and Psychol.,' article *Vision*.

argument mainly centers, occurs when he says, speaking of certain lucubrations of Edridge-Green, that they are an inadequate explanation 'of the trichromatism of normal vision, *which is a fact, not a theory*.' (Italics mine.) Now it is perfectly true that what Dr. Parsons here intends to refer to is a fact and not a theory; but it is not trichromatism, and it will never be generally accepted as a fact so long as it is called by that name. 'Trichromatism' is nonsense. Every psychologist knows (and many a physiologist, but no physicist) that vision is tetrachromatic, that there are four distinct chromatic sensations, Red, Yellow, Green and Blue. (I adopt the use of capital letters to indicate the exact, simple, unitary, chroma-sensations, while red (*e. g.*) with a small letter, may still be used loosely, as in real life, for a sensation which, though it may be slightly bluish or yellowish, a little 'off color,' still has redness for its predominant quality.) The fact which Dr. Parsons is here referring to is (if expressed in the terms demanded by our present knowledge of photochemistry) that the resonance curves which represent the response of the receptor substances of the visual apparatus to light are three in number, that the activity of the receptor apparatus can be expressed as a function of three variables, and that the area which gives point-to-point representation to distinct functions of stimuli is triangular in shape. In Fig. 2, *a*, the triangular character of light-ray mixtures is represented roughly; in Fig. 2, *b*, the exact spectral curve is reproduced. While the shape of this figure is triangular, as representing the facts of 'matching by mixtures,' that the result is tetrachromatic may be very simply but quite adequately represented by the four-fold character of the striations (or by actual pigments). I have called this the quadrigeminal (but triangular) color area,—it unites in one diagram the beloved color facts of Hering and of Helmholtz. (Quadrigeminal is reminiscent of the *corpora quadrigemina*.)

The tridimensional figure, of which this is a cross-section, is usually given as a double pyramid, but that is a total misrepresentation of the real state of things. There is no reason why the accompanying achromatic process and sensation (present, as is now well known, in the cones also together with the chromatic one) should not be represented. The correct diagram for this has been given in longitudinal section by Wundt,[1] and it is so important that I reproduce it here (Fig. 3) in the hope that it may come to take the place, in text-books, of the erroneous double pyramid. After

[1] 'Phys. Psychol.,' 4. Aufl., S. 537.

objective light has reached a certain (low) intensity an achromatic (prechromatic) sensation sets in, and increases from *b* to *w*. The chromatic constituent of the total sensation begins at *c* and takes the course *c r*. The dotted line indicates the chromaticity of the complex sensation,—it reaches a maximum at *m*, and then approaches zero. Wundt has represented the chromaticity as a difference,—it should, of course, be a ratio, but the principle is the same. A cross-section at any point of the solid of which this is the longitudinal section would give the color triangle at a given intensity.

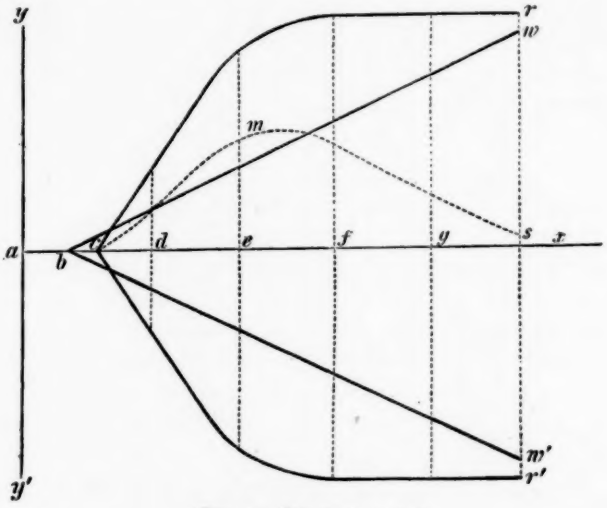

FIG. 3. See text, p. 243.

Exactly the same state of things as is depicted in the color triangle is given again, by another method of representation, in the three resonance curves of König (Fig. 4). The fact that Dr. Parsons has searched well the literature of color is evidenced by his giving these curves in their latest form—that required by the fresh determination of the intersecting points (the points where change of objective intensity causes no change of color tone) by F. Exner.[1] These curves differ from the similar, quadruple, curves of Hering, of course, in the circumstance that, while the latter are the pure work of the imagination, these are the result of the most exact measurements. This diagram ought to be adopted as the classical representation of these facts. Miss Steindler's determination of

[1] *Sitz. d. Wiener Akad.*, 1902, CXI., iia, 857.

the four points of maximum discriminibility for color tone (page 32) is also of critical importance.

It is on the side *R G* of the Helmholtz color-triangle (Fig. 2) that is exhibited the character of color vision which makes the Helmholtz color theory impossible: while on the other two sides light-ray mixtures are simply correlated with sensational color blends (the blue-greens and the blue-reds), as the theory requires, on the side *R G* what should be the red-greens are replaced by blends with an entirely new sensation, yellow. This has to be accounted for *without giving up* (as Hering does) the absolutely established laws of light-ray mixture, and the fact that the sensation systems of the dichromates are reduction-forms from those of the normally visioned. It is here, therefore, that it is absolutely necessary to

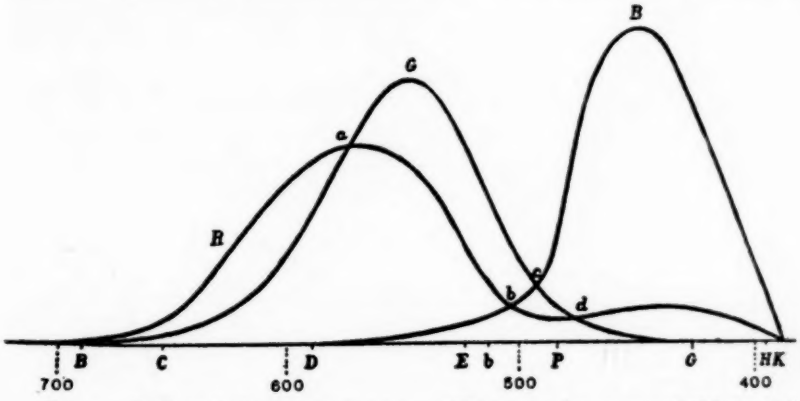

FIG. 4. *R*, *G*, and *B*, resonance curves. These are the curves of König and Dieterici corrected to new determinations of the points of section, *a*, *b*, *c*, *d*. Abscissæ, wave-lengths of the interference spectrum of the arc light; ordinates, arbitrary scale. (F. Exner.)

distinguish sharply between the visual stimuli, with their dissociation processes in the receptor substances of the retina, and the resulting nerve-excitations (with their attached sensations). But the curious thing is that Dr. Parsons himself is, upon occasion, perfectly aware of the necessity for noting this distinction. He knows well, and he explicitly states it in one good passage, that the specific light radiations are not yet chromas, but that a chroma is the conjoint effect of a specific, correlated, resonating, photo-chemical substance in the retina—the receptor mechanism—together with a nerve-end excitation and a nerve-fiber conduction, doubtless specific also, and excitable cortical (or sub-cortical) nerve cells. He

says that it is only in a 'broad' sense that you can speak of objects, or of radiations, or radiation-groups, as being colors,—he should say that it is only in a popular and wholly inaccurate sense that you can speak of them as such; they are really nothing but red-producing, chromatogenic, erythrogenic, xanthogenic, etc., objects and rays. The confusion which is here so fatal we owe, of course, to our primitive ancestor, the naïve realist. The situation is, however, equally fatal to every form of realism, as has often been pointed out, and brilliantly by Professor Lovejoy. In most of our interests, both scientific and non-scientific, this ambiguity does not trouble us, but occasions may at any moment arise when (as in the present instance) it is of very great import. One should, therefore, even if one does not at once use it for every day, have an adequate terminology at hand for those occasions when to distinguish between sensation and the physical correlate of sensation is an absolute necessity.

The very discreditable state of color discussion which has been kept up for fifty years may then be summed up in a word in this way. The theses maintained by the adherents of the two rival schools are these:

Helmholtz	*Hering*
Trichromatism is a fact.	Tetrachromatism is a fact.

These are evidently two absolutely contradictory statements, but both true. *Que faire?* At this point I felt myself obliged to interfere, with (1) a reformed terminology, and (2) an adequate color theory. I substitute for the above two statements this:

The Development Theory

> Tri-receptorism is a fact and tetrachromatism is a fact, and these two facts are reconciled in the development color theory,—indeed, they constitute its ground work.

To reproduce, in a word, my color theory (for which Fig. 5 offers mnemonic support): a light sensitive substance in the visual elements (the rods) in primitive times, when vapor-laden skies and phanerogamic plants afforded no chromas to be seen, responded indifferently to all parts of the spectrum; W, the ionic mass thrown off (photochemical reactions are now often supposed to be a form of ionization), became a nerve-end excitant to which was attached in the cortex the sensation of whiteness. In more highly developed animals—as in the bees (v. Frisch)—this cleavage product became more highly differentiated, and was capable of responding specific-

ally to the warm end and the cold end of the spectrum, furnishing respectively the sensations yellow and blue; but when both of these cleavage products are dissociated out at once, they reunite to form the whiteness nerve-excitant, *W*, out of which they were formed, after the analogy, for instance, of an acid and a base, which, being the constituents of a neutral salt, cannot (except in solution) exist separately. This form of vision persists in the partially color blind and in the mid-periphery of the normal eye. A farther specialization of response to light-rays provides 'red' nerve-excitants and 'green' nerve-excitants, but, as before, red-greenness fuses into the yellowness *out of which it was developed*, while the blue-greens and the blue-reds persist as simple chroma-blends. An exact chemical analogy for this situation can be given.[1]

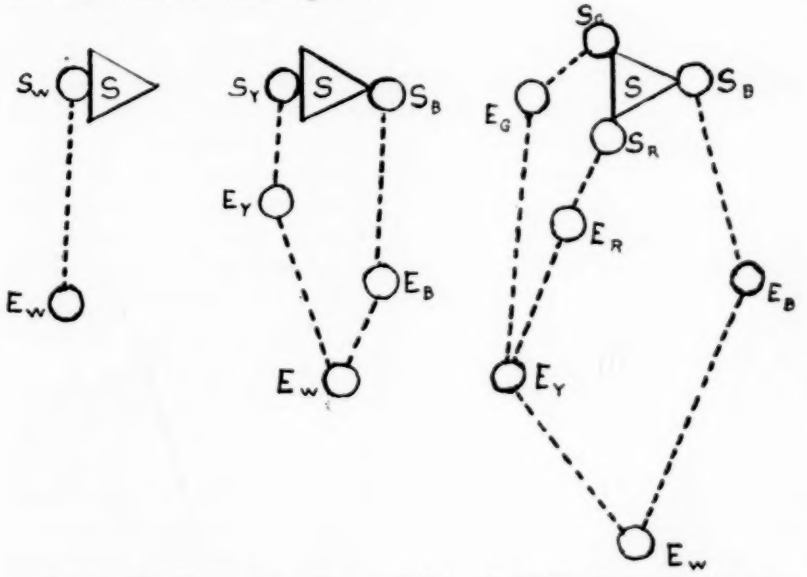

FIG. 5. The Development Theory of Color (Ladd-Franklin). SN, the color-sensation receptors (resonators, side-chains, light-sensitive ions, or whatever the current photo-chemical theory may demand), in three successive stages of development. EN, the five specific nerve-excitant substances for the five specific light-sensations.

It will be seen that my theory is built about the evident consideration that the lack of the power to perceive the yellowish blues and the reddish greens of nature—the extinction of yellow-blue and of red-green into white and yellow respectively—is a *defect* in the

[1] See 'Am. Encyc. of Ophth.,' Art. *Color Theory*.

visual mechanism,—a *défaut de ses qualités*. The best thing that could be done, given the problem of developing light-sensitive substances in the way of making wave-lengths discriminable, has been done, subject to the restriction that the whole process must be carried out in a single visual element; physically adjacent cones (unlike the mechanism for auditory specificity) needed to be utilized for a highly specific space-sense. Any color theory therefore (Preyer, Bernstein, Troland) which devises a special mechanism for the *express purpose* of making us blind to the yellow-blues and the red-greens is by that circumstance *von vorn hinein* condemned.

Some criticisms which Dr. Parsons makes of my color hypothesis may be replied to briefly as follows:

1. Nowhere in his book does Dr. Parsons make a more thoroughgoing mixing up of fact and theory than when he says that my theory is an 'offspring' of the Helmholtz *theory*. My theory takes in the Helmholtz three-stimuli *facts*—why should it not, when it was expressly devised for the purpose of bringing under a single, simple, physiological conception both those facts and the facts of tetrachromatism?—but it is as far removed as possible from the Helmholtz *theory*, which is incompatible with tetrachromatism. It might just as well be said to be an offspring of the Hering theory because it takes in the Hering facts. But every theory which deserves the name must, since Hering wrote, take in *both* the fundamental facts which are made much of by Hering and those which are made much of by Helmholtz.

2. The connection between my theory and that of Donders I have already discussed.[1] As I have just said, no theory can be proposed (since Hering's) which fails to take in both the three-stimuli view and the tetrachromatic one. Donders's theory is much more like Hering's than like mine, for a fundamental point of mine is the unique character which it assumes for yellow. Yellow is beyond question, of course, a unitary chromatic sensation, but it is far from being in all respects the same sort of thing as the other unitary chromas, any more than it is the same sort of thing as the product of the other light mixtures, the green-blue and the blue-red chroma-blends. For one thing, there are occasions (McDougall) when red and green light stimuli effects do not fuse completely, but give rapidly alternating, or possibly simultaneous, red and green sensations. In my theory the fusion of the red and the green nerve-excitants is a secondary phenomenon, and there is no reason why, under certain conditions, it should not fail to take place,—exactly

[1] *Johns Hopkins University Circular*, 1893.

(to return to my analogy) as a salt in solution is now regarded as being always partly in a state of dissociation.

3. Hering's explanation of simultaneous contrast is purely a verbal explanation. Since it has become known (Tschermak, Fernald) that simultaneous contrast is produced in supraretinal regions (also, at least, if not only), satisfactory explanations of it would be hard to discover. No one states more forcibly than Dr. Parsons that theoretical explanations in regions where facts have not yet been completely made out are waste of time. Simultaneous contrast *over wide regions* is doubtless an electrical phenomenon of some sort, attendant upon the main events of nerve fiber excitation (as suggested by Troland). Tashiro's brilliant discovery of the increased giving off of CO_2 during the passage of a nerve current may be suggestive in this connection, and so may the subjective vision of the nerve current in the nerve fibers of the retina—that remarkable fact which has had six independent discoverers, Purkinje the first, and which is still nevertheless almost unknown.

4. Dr. Parsons suggests the addition of a core of undifferentiated atoms to my assumed light-sensitive (resonating) molecule. One thinks of selective dissociation by light now, of course, in terms of side-chains or electrons (or probably, by this time in terms of magnetons) attached to a residual substance. But even at the time I wrote my first article on this subject my assumed molecule had already a 'core' for the support of its resonating attachments, as Dr. Parsons would see if he were to look at my original diagram, and in fact I expressly mention its importance.[1] But the real answer to the supposed objection here intended (an objection which shows complete failure to understand the theory) is that (to repeat my analogy) if a salt were added to something in a test tube the effect would be the same as if there were added to it the acid and the base out of which the salt is constituted. It is, in fact, the theory of v. Kries (not mine) which is made impossible by the circumstance that there is no reason why his foveal white should look like his rod white, since their supposed physiological substrates are entirely different; my criticisms of his views on this point have been explicitly accepted by Professor Hering.[2]

Dr. Parsons's book, however, in spite of fundamental points in which I maintain that it is open to criticism, can be safely recommended as indispensable in any place where the science of color-sensation is under serious consideration.

[1] *Zsch. f. Psychol.*, 4, page 6.

[2] *Pflüger's Archiv*, 1907.